ECOSYSTEM SERVICES ESTIMATION FOR DEPRESSIONAL WETLANDS IN THE HIGH PLAINS REGION: SAMPLING MANUAL FOR THE INTEGRATED LANDSCAPE MODELING PARTNERSHIP

Hydrogeomorphic Classification and Ecosystem Services

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Chapter 1: Introduction

Wetlands across the United States are valuable as natural and unique ecosystems. Their social and economic importance can be described through the ecosystem services they provide to individuals and societies (Millennium Ecosystem Assessment 2005). Services include but are not limited to wildlife habitat, water filtration, floodwater storage and carbon sequestration (Millennium Ecosystem Assessment 2005). Over 230,000 ha of vegetated, freshwater wetlands in the conterminous United States were converted to other land-use types from 1974 to 2009, and conservation of remaining wetlands has become a nationwide priority (Dahl 2011).

This manual was developed for use by the Integrated Landscape Modeling (ILM) partnership which focuses on modeling wetland ecosystem services and is described in the next section. The manual can be applied in the High Plains Region (HPR) where playa wetlands are dominant. This region was designated by the U.S Department of Agriculture (USDA) Conservation Effects Assessment Project (CEAP) wetlands component (CEAP—Wetlands), which evaluates the effects of landowner assistance conservation programs on wetland resources (Duriancik et al. 2008) (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/na/?cid=nrcs143_014155). This manual includes instructions on identifying the hydrogeomorphic (HGM) classification of wetlands and waterbodies in the HPR as well as models for estimating ecosystem services of playa wetlands and their vegetative buffers. Numerous models are included, and many are predictive regression equations based on field data. The techniques and models in this manual provide information regarding the function of playa wetlands in the HPR and can be applied through use of remotely sensed data. Estimation of ecosystem services can be carried out for historic as well as current and future conditions to determine how services have changed and will potentially change under different land use types.

Users

Integrated Landscape Modeling (ILM)

The ILM Partnership was established in 2004 with the goal of identifying, evaluating and developing models for the purpose of quantifying wetland ecosystem services. The focus of the partnership was originally on wetland systems and their response to USDA conservation programs and practices (Mushet and Scherff 2016). Initial ILM work centered on northern prairie wetlands in the CEAP Prairie Pothole Region (PPR). The Integrated Valuation of Ecosystem Service Tradeoffs (InVEST) modeling platform was used in the PPR for landscape scale ecosystem service valuations (Mushet and Scherff 2016).

The CEAP—Wetlands ILM effort in the HPR developed predictive regression models that estimate ecosystem services of playa wetlands and their vegetative buffers. This manual can be applied by ILM partners and others to predict ecosystem services provided by playa wetlands and determine the effects conservation programs and practices have on these services. Historic, current and future condition estimates provide critical information to policy makers for the management of these important and unique wetlands.

Conservation Users

Land managers or researchers in the HPR can use this manual to determine the function of a wetland or other waterbody, or to predict the ecosystem services of a playa or its vegetative buffer. Most of the required data are available online through land-use datasets, topographic maps, hydrography maps, satellite imagery, and spectral reflectance data. The HGM key and predictive models can be applied using a Geographic Information System (GIS) and can be re-applied to demonstrate changes between differing land use types or altered playa condition. For predicting ecosystem services, current land use may need to be identified or estimated for model application. Federal Conservation Reserve Program (CRP) land can be identified by users with access to confidential CRP spatial data, but determination is not required for this manual to be useful. Other land use types can be identified using publicly accessible data and services can be estimated for those types. In this case, CRP specific regression equations could be used without the need for CRP spatial data and could model the potential services provided if land use were converted to CRP.

The National Resources Inventory

The National Resources Inventory (NRI) is a largescale inventory focused on land use, soil erosion and water resources on private lands nationwide (U.S. Department of Agriculture 2018). It is carried out by the USDA Natural Resource Conservation Service (NRCS) and tracks changes in natural resources over time (Nusser et al. 1989). Wetlands and deepwater habitats encountered at sample locations are identified according to their Cowardin et al. (1989) classification and reported in net gains and losses by system type. The inventory is a robust dataset that has the potential to provide detailed information about depressional wetlands and the ecosystem services they provide.

This manual extends the work done by the NRI by introducing techniques which could be added to infer wetland function and estimate ecosystem service provisioning in the HPR. Here we explain how ecosystem service estimations could be carried out for playa wetlands using the included models and remotely sensed data. Integrating the methodologies and models presented in this manual could add to the valuable information gained by NRI assessments and provide further details regarding the state of the Nation's wetland resources in the HPR.

Depressional Wetlands

High Plains Region (HPR)

Eleven assessment regions (Figure 1-1) were identified by CEAP—Wetlands based on the dominant, naturally formed wetland type in the area (Eckles 2008). In the HPR (Region 7 in Figure 1-1), the dominant wetland type is a depressional wetland known as a "playa wetland", "playa lake" or simply "playa". Playas exist throughout portions of Texas, New Mexico, Oklahoma, Colorado, Kansas and Nebraska (Figure 1-1) (Haukos and Smith 1994). The majority of the HPR exhibits variable rainfall amounts with evapotranspiration exceeding precipitation, and much of the region is therefore considered semiarid (Bolen et al. 1989). Annual precipitation averages can range from 30 to 63 cm with annual evaporation between 165 and 284 cm (Smith 2003). Topography is fairly flat, and natural upland vegetation type consists primarily of prairie grasses, but large portions of the region have been converted for agricultural production (Bolen et al. 1989).

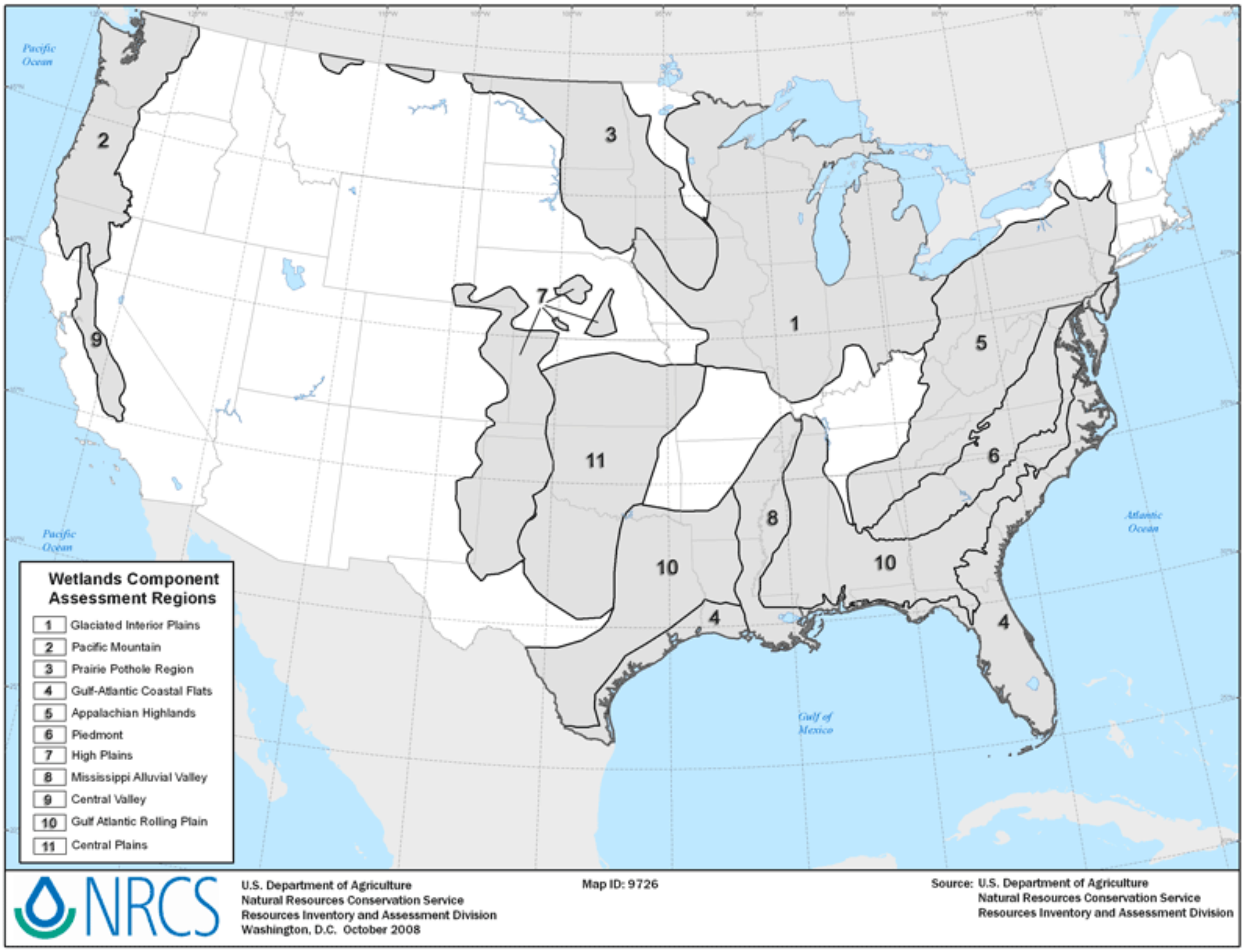

FIGURE 1-1. THE ELEVEN CONSERVATION EFFECTS ASSESSMENT PROJECT (CEAP)—WETLANDS REGIONS IN THE UNITED STATES. THE HIGH PLAINS REGION (HPR) IS LABELED AS REGION 7. IMAGE FROM ECKLES (2008).

HPR SUBREGIONS

The region where playas exist has been divided into subregions due to differing climate, topography and land management practices. The HPR is mostly comprised of the Western High Plains (WHP) subregion but also includes the Rainwater Basin (RWB), which sits south of the Platte River in south-central Nebraska. (Figure 1-2, Figure 1-3). The WHP is topographically flat and is often split into three portions known as the Northern, Central and Southern High Plains (Figure 1-2). The RWB is a landscape of rolling plains and this topography has historically allowed playas in the RWB to be more easily drained for agriculture, resulting in a greater amount of wetland loss (LaGrange 2005, Smith 2003). Federal conservation programs differ between the regions with the Conservation Reserve Program (CRP) being more commonly applied in the WHP while the Wetlands Reserve Program (WRP), now carried out as the

Wetland Reserve Easement (WRE) under the Agricultural Conservation Easement Program (ACEP), is more commonly applied to playa wetlands in the RWB (Ferris and Siikamäki 2009). The goals and practices of these programs have differing consequences for wetlands in their respective regions. Conservation program effects have not been explored in the Central Table Playas and the application of techniques in this manual are not recommended for use here.

Numerous predictive ecosystem service models were built based on playa data from the HPR but some datasets were restricted to the WHP subregion, the Northern High Plains (NHP), Southern High Plains (SHP) and the RWB. Because the data used to develop these models were restricted to certain subregions and portions, a user must take caution if seeking to apply these models to playas within a different area.

The RWB physiographic area, as recognized by the Rainwater Basin Joint Venture (RBJV), is continuous along the southern edge of the Platte River, and playas are present throughout (Figure 1-3). The High Plains Region as designated by CEAP—Wetlands only includes certain portions of the larger RWB physiographic region (Figure 1-2). Our manual was built specifically for the HPR as designated by CEAP—Wetlands but models would be applicable across the extent of the RWB physiographic area shown in Figure 1-3.

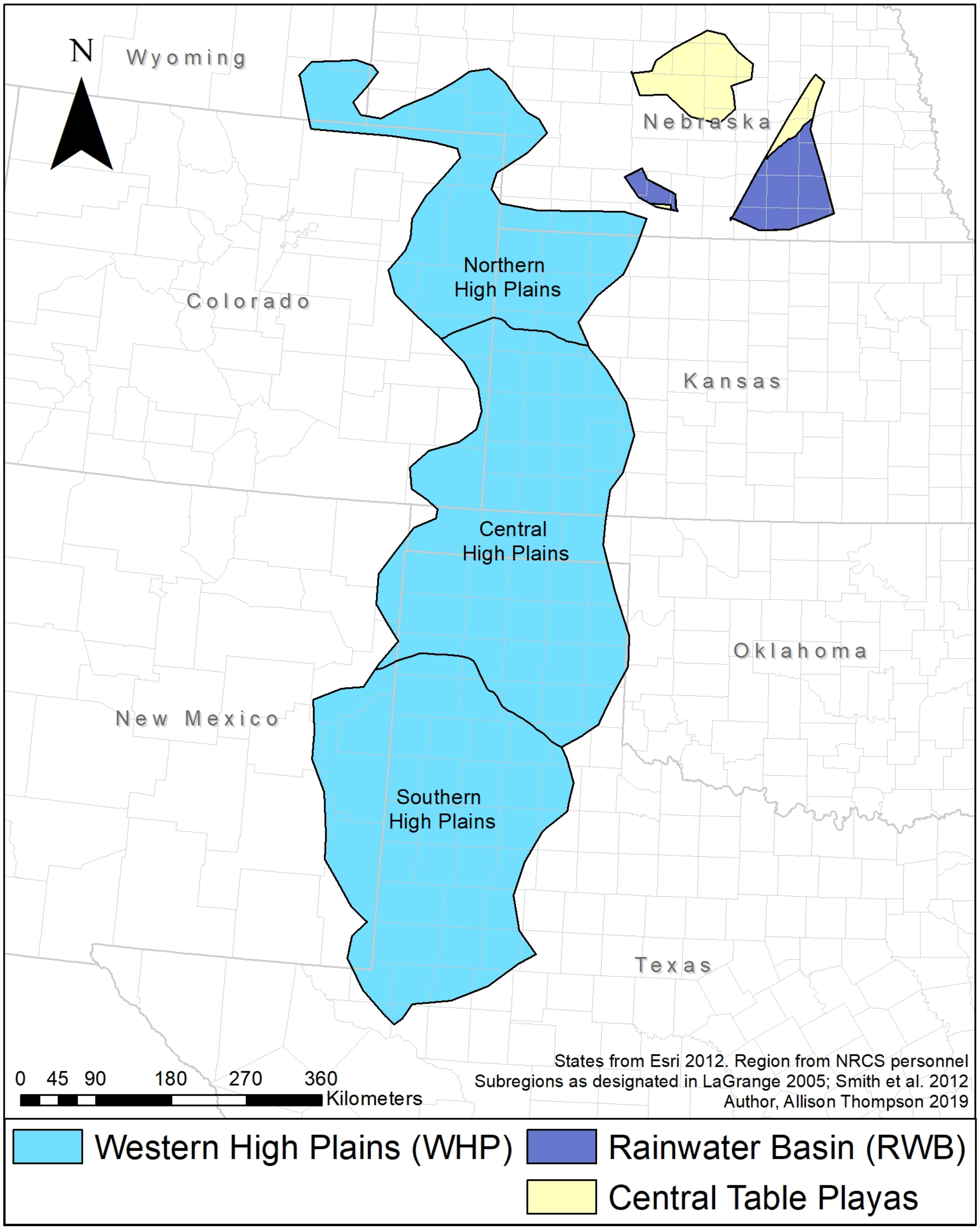

Figure 1-2. Subregions and portions of the Conservation Effects Assessment Project (CEAP) – Wetlands High Plains Region (HPR) as designated by models selected for this manual. Subregions and portions as designated by LaGrange (2005) and Smith et al. (2012). Data from ESRI (2017), Rainwater Basin Joint Venture (2018) and personal communication with William Effland (2017).

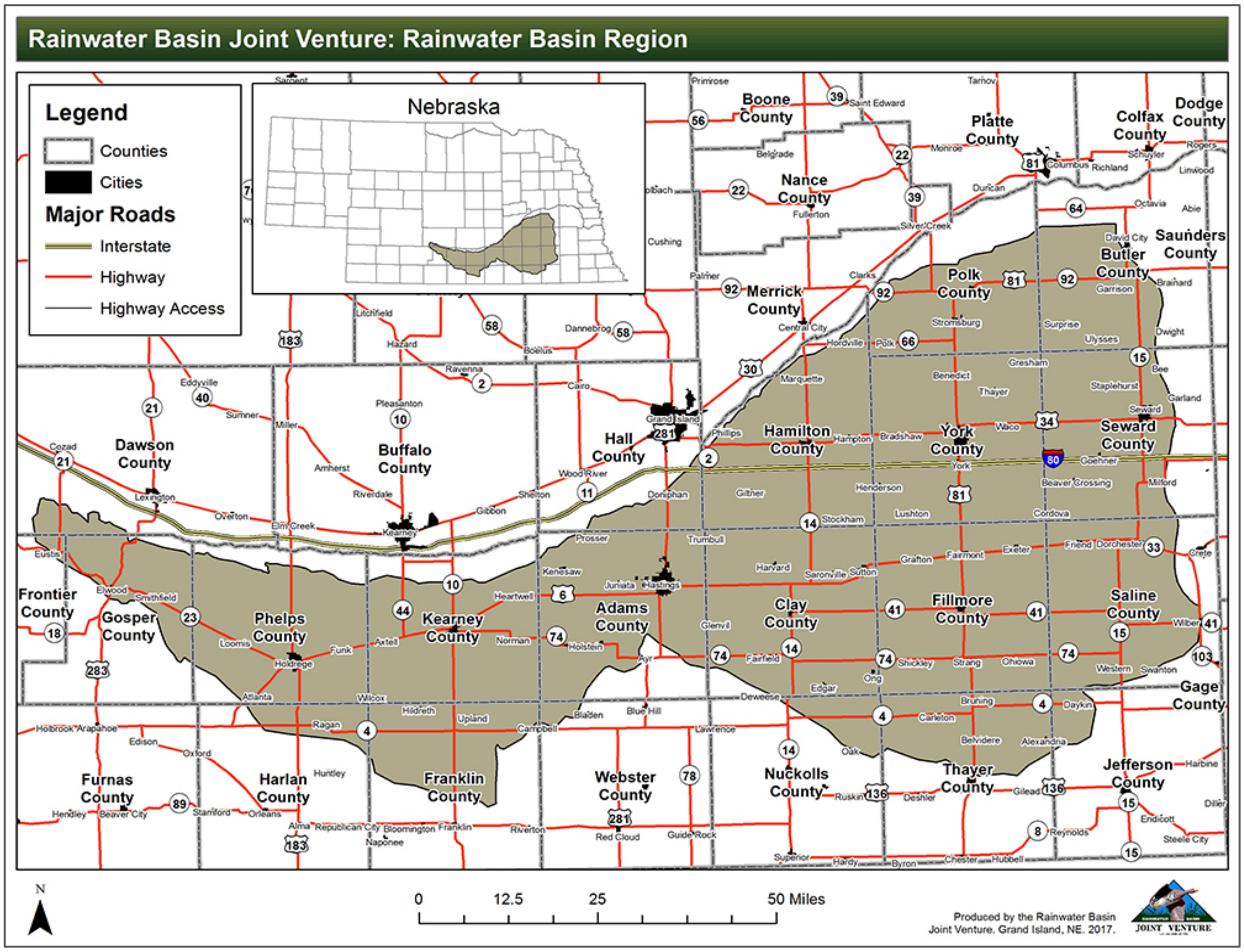

FIGURE 1-3. RAINWATER BASIN (RWB) PHYSIOGRAPHIC REGION. FROM RAINWATER BASIN JOINT VENTURE (2018).

PLAYAS

Playas are shallow, depressional, recharge wetlands characterized by having a closed watershed and receiving water through precipitation and overland flow (Smith 2003, Tiner 2003). Hydroperiod, i.e., the length of time a playa contains standing surface water, is variable and highly dependent upon precipitation events. Playas in the WHP tend to have a circular shape and be less than 2 m deep. Sizes range from less than 1 ha up to 400 ha, but the majority are less than 12 ha in size (Smith 2003). Playa formation is attributed to wind and wave as well as dissolution processes (Haukos and Smith 1994; Reeves and Reeves 1996). Dissolution occurs when decomposition of organic matter results in the production of carbonic acid in a low point on the landscape where water has accumulated. This carbonic acid causes calcium carbonate in the soil to dissolve, forming a shallow basin with a flat bottom (Osterkamp and Wood 1987). Playas within the RWB exhibit a more oblong shape when compared to WHP playas since formation occurred through wind and wave processes (LaGrange 2005). Although slightly different in shape, RWB playas are similar in size and carry out the same wetland functions (Smith 2003).

Ecosystem Services

DEFINITION

Ecosystem services are defined as the natural processes or functions of a system that provide environmental benefits to humans (Millennium Ecosystem Assessment 2005). Costanza et al. (1997) estimated that the global monetary value of ecosystem services could total more than $33 trillion per year. Services are provided by a variety of systems including, but not limited to, forests, grasslands, stream systems and wetlands. Ecosystem services are often grouped into four categories: supporting, provisioning, regulating and cultural (Millennium Ecosystem Assessment 2005). Supporting services affect all others through primary production, nutrient cycling and soil formation. Provisioning services include food, water and fiber production, while regulating services include flood regulation, climate regulation and water purification. Services related to culture include those which are educational, recreational, aesthetic and spiritual. Wetlands provide numerous services within each of these four categories but have been estimated to have a greater annual value per hectare regarding disturbance regulation, waste treatment and habitat provisioning when compared to other biomes (Costanza et al. 1997).

WETLANDS

Monetary valuation of wetland ecosystem services has been estimated at $4 trillion globally per year (Costanza et al. 1997). Depressional wetlands specifically have been shown to provide services such as floodwater storage, groundwater recharge, biodiversity support, carbon sequestration, sediment reduction and nutrient reduction (Smith et al. 2011). In playas, it has been observed that surrounding land use is a primary driver of wetland function and therefore services. For example, carbon storage in the soil of playa wetlands was decreased by approximately 20% when surrounding land was in cultivated crops (O'Connell et al. 2016). Sediments carried by overland water flow can fill the basin of a depressional wetland, decreasing both water volume and hydroperiod. Because the function of a wetland provides many services to humans, degradation in the quality and function of depressional wetlands by sediment infilling can have a negative impact on the services provided (Tsai et al. 2007). Thus, knowledge of wetland functions over time provides valuable information needed for the future conservation and management of the Nation's wetland resources.

Wetland Classification

COWARDIN ET AL.

Wetlands are commonly classified according to the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979), hereafter referred to as the Cowardin classification. The Cowardin classification was developed to bring uniformity to the terminology used in identifying wetlands in order to avoid inconsistent labeling. The classification is organized as a hierarchy comprised of systems, subsystems, classes, subclasses and modifiers. Classification of a wetland is based on both abiotic and biotic features including size, depth, water movement, substrate structure and type, and vegetation structure and type. The Cowardin classification can be used to describe wetland habitat types and to track net gains and losses of wetlands by system type. This system has many beneficial uses but it was not built with a focus on wetland function. Identification of some additional features can provide an understanding of ecosystem service provisioning.

The Cowardin classification is used in the National Wetlands Inventory (NWI). The NWI provides a database developed by the U.S. Fish and Wildlife Service (FWS) with the goal of mapping and classifying all wetlands nationwide (Dahl et al. 2015). Data in the NWI was compiled from aerial imagery, and wetlands are denoted by digital polygons and classified according to the Cowardin classification. This database can be accessed in The Wetlands Mapper on the FWS website (https://www.fws.gov/wetlands/data/mapper.html). National Wetland Inventory data are used by many researchers and inventory projects to identify the location and classification for wetlands of interest.

Palustrine wetlands are the most widely encountered wetland system in the Cowardin classification. However, due to the focus of this classification system, few inferences can be made about the services palustrine wetlands provide. These wetlands are shown to make up 66% of 64.7 million ha of wetlands observed in the NRI and are described as shallow, inland, freshwater systems defined as being mainly non-tidal with emergent vegetation dominating the wetland area (U.S. Department of Agriculture 2018). Palustrine wetlands have no maximum size limit, but if vegetation is lacking, they must be less than 2 m deep at low water (Cowardin et al. 1979). Most playas are classified as palustrine wetlands with other palustrine types including drainage ditches, waste treatment lagoons and excavated ponds. Although the Cowardin classification identifies characteristics that are shared between these waterbodies and naturally formed wetlands, differences in the function of differing types of palustrine wetlands can be great.

HYDROGEOMORPHIC (HGM)

Another broadly used wetland classification system is the Hydrogeomorphic (HGM) classification. The HGM classification was developed by Brinson (1993) for the purpose of classifying wetlands according to function. Because this classification system helps provide function information, it can be used in addition to Cowardin to identify potential ecosystem services. The HGM classification is based on abiotic factors, resulting in wetland groups that share similar function. This classification identifies three features that drive wetland function: geomorphic setting, water source and hydrodynamics (Brinson 1993). Geomorphic setting is defined as the wetland's position within the surrounding landscape. Water source identifies primary water inflows to a wetland, while hydrodynamics identifies potential outflows and other water movements.

Seven geomorphology types have been established and include depressional, riverine, tidal fringe and lacustrine fringe (Smith et al. 1995). A waterbody with depressional geomorphology sits within a closed watershed. The primary water source is often overland flow with evapotranspiration and groundwater recharge as common hydrodynamics (Natural Resource Conservation Service 2008). A waterbody with riverine geomorphology is situated within or adjacent to a streambed with water sources being overland flow and streambank flooding. Hydrodynamics in riverine wetlands can include bidirectional flow in and out of the stream during changing stream levels (Natural Resource Conservation Service 2008). With knowledge of abiotic factors, the function of a waterbody can often be inferred. For example, when the primary water source is overland flow, and hydrodynamics include spilling into a stream or other waterbody, it is understood that some portion of water is being held in the wetland and therefore floodwater is being stored.

Depressional Wetlands in the Palustrine Class

PALUSTRINE VARIABILITY

When identifying wetlands in the Great Plains using the Cowardin classification, there are a variety of functional types can become grouped. Palustrine waterbodies may include naturally formed depressions, pools associated with intermittent streams, wetlands adjacent to streams, man-made ponds, drainage culverts and lagoons. Modifiers are available to describe flooding regimes and mechanical alterations/formation, but these are not able to consistently distinguish playas from other wetland types. When waterbodies are labeled using the Cowardin classification, it becomes difficult to distinguish natural, closed depressions from other waterbody types.

PALUSTRINE EXAMPLES

In the HPR, two palustrine wetlands with the same Cowardin classification label were observed using satellite imagery (Figure 1-4). These both were labeled as PEM1C in the NWI, which translates as palustrine system, emergent class, persistent subclass and seasonally flooded. When the HGM classification is applied, the first wetland is considered depressional and the second is considered riverine. The first can be identified as a playa in a closed depression while the second appears to be a riparian area which may hold intermittent overbank flow. When HGM is considered along with the Cowardin label it can highlight the different functions occurring between these wetland types allowing ecosystem services to be inferred.

FIGURE 1-4. TWO NATIONAL WETLANDS INVENTORY (NWI) WETLANDS IN THE HIGH PLAINS REGION (HPR). BOTH ARE CLASSIFIED AS PALUSTRINE, EMERGENT, PERSISTENT AND SEASONALLY FLOODED (PEM1C) ACCORDING TO THE COWARDIN ET AL. (1979) CLASSIFICATION SYSTEM. THE WETLAND ON THE LEFT IS CLASSIFIED AS AN HGM DEPRESSIONAL AND IS A PLAYA. THE WETLAND ON THE RIGHT IS CLASSIFIED AS AN HGM RIVERINE AND IS WITHIN THE RIVER FLOODPLAIN. DATA FROM ESRI (2018) AND U.S. FISH AND WILDLIFE SERVICE (2017).

This Manual

PURPOSE

This sampling manual was built for use by ILM partners and by others in the conservation community to determine general function or specific ecosystem services for depressional wetlands within the High Plains Region of CEAP—Wetlands. The most common wetland type in this region is the playa wetland. Understanding wetland function is necessary when establishing the status or changes of wetland resources over time. Knowledge of change is important for policy makers faced with decisions on future conservation laws and practices influencing wetland resources.

HYDROGEOMORPHIC KEY (CHAPTER 2)

A key for applying the HGM classification to waterbodies in the HPR has been developed for understanding function using the NWI GIS database to identify wetland presence. Abiotic features identified in the HGM classification allow function to be inferred. The combination of biotic and abiotic features required in the Cowardin classification result in the placement into a single group wetlands and waterbodies that are functionally very different. The HGM system is more capable of identifying the variety of functional types found within the Cowardin classification’s palustrine system. The HGM key included in this manual can be applied on any palustrine waterbody within the HPR and can be carried out entirely through remote sensing. This key identifies broad HGM classes as well as more detailed wetland features that are likely to be encountered within the region; this includes identifying playa wetlands specifically. Determining HGM classification would allow the ILM to infer wetland function for most waterbodies found within the HPR.

ECOSYSTEM SERVICE ESTIMATES (CHAPTER 3)

Predictive regression models were included to determine the ecosystem services provided by playa wetlands and their vegetative buffers under specific land-use conditions. If a waterbody in the HPR is identified as a playa using the HGM key provided, further information can be determined using the predictive models included in the final chapter of this manual. Predicted values are based on relationships between wetland features that have been identified from field data. Many services are related to surrounding land use, waterbody size and adjacent vegetation type. All features required to predict services can be determined remotely, and detailed instructions for gathering these data are included. A list of the metrics that must be collected is included (Appendix A). Datasheets are also included for simplified organization of data (Appendix B). Using these models, the ILM partners and other users would be able to estimate current playa ecosystem services and track changes over time.

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Chapter 2: HGM Classification Key

The HGM Key

THE HYDROGEOMORPHIC CLASSIFICATION

The Hydrogeomorphic (HGM) wetland classification system was established by Brinson (1993) as a function focused approach to classifying wetlands. The HGM classification can determine ecosystem services that might be provided by a wetland based on functions identified through geomorphic setting, water source and hydrodynamics. For example, if geomorphic setting is identified as riverine, water source is overland flow from the upland, and hydrodynamics release water into a stream, it can be understood that water filtration is a service that is likely occurring. Similarly, if a depressional wetland receives water from the upland and withholds that water until evapotranspiration occurs, it is understood that floodwater storage is provided by the basin which alleviates flooding in the upland. The key included in this chapter has been developed to determine the HGM class for wetlands and other waterbodies in the Conservation Effects Assessment Project (CEAP)—Wetlands High Plains Region (HPR).

GENERAL PURPOSE USES

- Only applicable for wetlands and waterbodies in the HPR as designated by CEAP—Wetlands.
- Only applicable for wetlands and waterbodies identified as palustrine class in the Cowardin classification.
- Uses remote sensing through topographic maps, satellite imagery and other spatial datasets. A GIS is required to determine wetland classification.
- Depressional wetlands identified as playas can further be assessed using models in Chapter 3 of this manual to estimate ecosystem services.

GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING

DATA SOURCES

Selected data sources should be of equal or greater reliability compared to the recommended sources. Topography for example, may be available at higher resolutions or from more direct measurement methods such as LiDAR derived Digital Elevation Models (DEM). It must be noted, if ecosystem services are to be compared across time, or between wetlands, the same data sources must be utilized for accurate comparison. For this reason, we have selected data that are present across the entire region and are accessible to most users.

National Wetland Inventory (NWI): this dataset was established by the U.S. Fish and Wildlife Service (USFWS) and identifies all wetlands and waterbodies across the United States via aerial imagery. Polygons represent wetland and other waterbodies by their location and attribute data includes

Cowardin classification. Data can be downloaded by state from the USFWS website (https://www.fws.gov/wetlands/data/State-Downloads.html).

National Hydrography Dataset (NHD): was developed by the U.S. Geological Survey (USGS) and consists of digitized flowlines representing streams and rivers across the United States. Stream location can determine the water source of a wetland. Data can be accessed as shapefiles within a file geodatabase through The National Map (TNM) (https://viewer.nationalmap.gov/basic/).

USGS Topographic Maps: were developed by the U.S. Geological Survey (USGS) and can be downloaded directly from The National Map (TNM) in geo.pdf format (https://viewer.nationalmap.gov/basic/). A digital continuous version of the USGS developed map is also available through ESRI as a basemap in the ArcGIS program (http://www.arcgis.com/home/item.html?id=99cd5fbd98934028802b4f797c4b1732).

Satellite Imagery: recent imagery can be accessed through Earth Explorer where Landsat 8 scenes can be downloaded for the location of interest (https://earthexplorer.usgs.gov/). Smaller features such as constructed dikes, pits and drainage canals can be detected using this imagery. Historical Landsat imagery is also available.

COORDINATE SYSTEMS

For observing maps and other spatial data, the authors recommend 'NAD_1983_Albers' as the coordinate system. This system is used by the NWI and limits area distortions across the extent of the United States (for more information see https://www.fws.gov/ wetlands/data/Projection.html). When using a GIS to observe numerous datasets, which may include vector and raster type data, the data frame and all data layers should have matching geographic and projected coordinate systems. This prevents measurement and location errors between data layers. Transformations between coordinate systems may be required.

- Coordinate System: North American Datum 1983 Albers (NAD 1983 Albers)
    - Datum: North American 1983 (NAD 1983)
    - Geographic Coordinate System: GCS North American 1983
    - Projected Coordinate System: Albers Conical Equal Area

Application of the HGM Key

INSTRUCTIONS

When a waterbody is located in the HPR, *and* it is identified as palustrine through the NWI, the following HGM key can be applied.

REGION IDENTIFICATION

Across the U.S., wetland regions have been identified for CEAP—Wetlands work. This manual can be applied for all depressional wetlands in the HPR regardless of subregion type (Figure 2-1). CEAP—Wetland region details are available on the NRCS website (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/na/?cid=nrcs143_014155).

WETLAND COWARDIN CLASS AND SHAPEFILE(S)

The National Wetlands Inventory (NWI) has produced shapefiles and Cowardin et al. (1997) titles for all wetlands and waterbodies in the United States. Due to the nature of the Cowardin classification, some wetland basins may have numerous wetland types present. All shapes that sit within a topographic wetland basin should be included when measuring wetland size.

This key may also be applicable on playas that have been classified as lacustrine waterbodies under the Cowardin system. The authors observed numerous potentially mis-classified depressional wetlands that were placed in the lacustrine class in the NWI. Since playas are generally less than 2 m deep, they do not exhibit the features necessary to be placed in the lacustrine class. Utilizing this manual, the HGM key could be applied to correct such misclassifications.

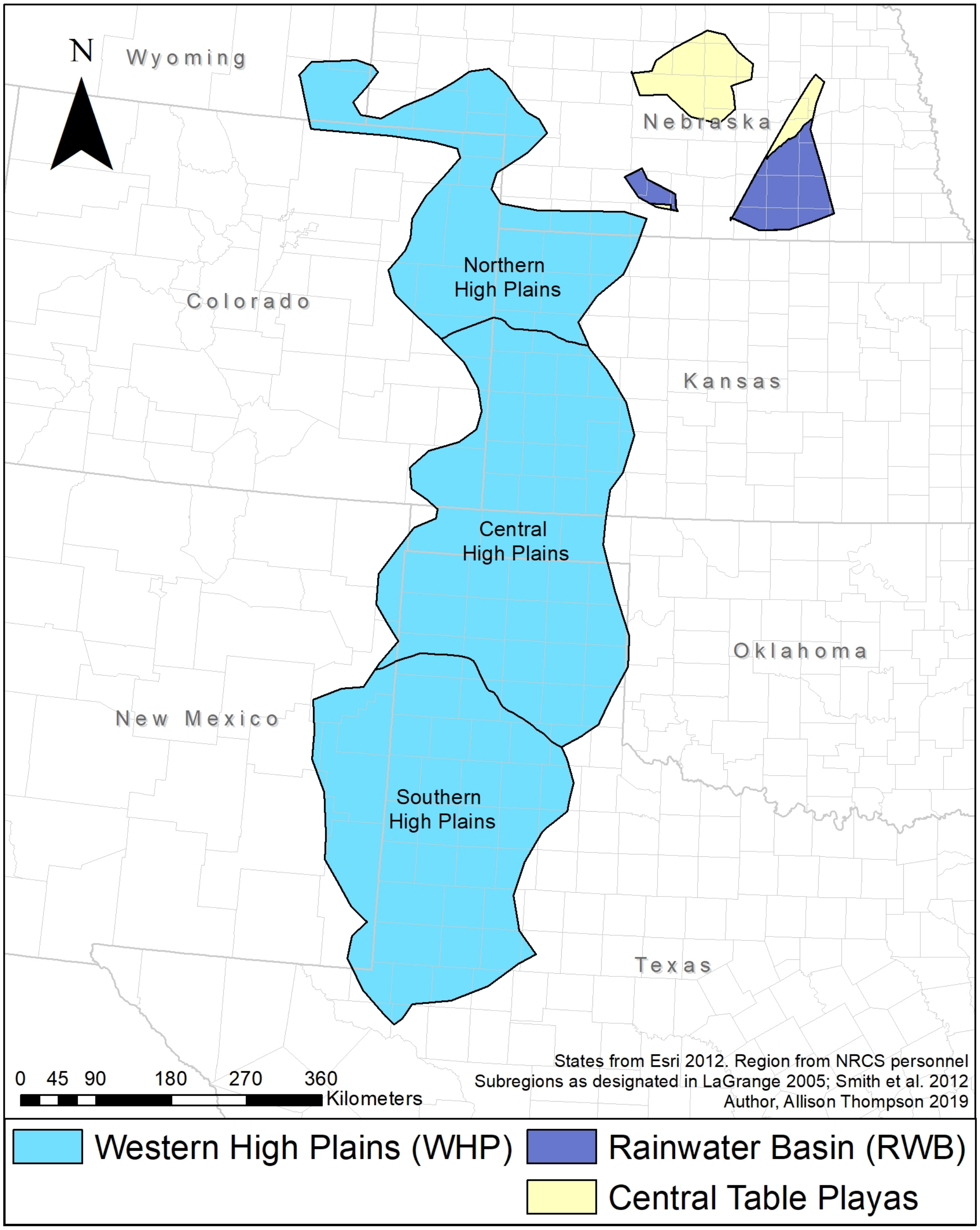

Figure 2-1. Subregions and portions of the Conservation Effects Assessment Project (CEAP) – Wetlands High Plains Region (HPR) as designated by models selected for this manual. Subregions and portions as designated by LaGrange (2005) and Smith et al. (2012). Data from ESRI (2017), Rainwater Basin Joint Venture (2018) and personal communication with William Effland (2017).

DEFINITIONS

Associated: intersects with the stream line or its topographically connected basin

Bend (Stream): a change in direction of the stream

Closed Watershed: due to topography, water cannot exit the watershed via overland flow

Diked: a structure has been human-built to retain water or slow the movement of water

Drainage: an intermittently wet location where water moves from higher elevation to lower elevation

Excavated: mechanical alteration is evident through straight edges or hard corners of a waterbody

Floodplain (Stream): an area which a stream can topographically supply water to during flood events

Lake/Reservoir Edge: a permeant waterbody which can supply water to an adjacent waterbody

Natural and Continuous Stream: all streams that are not human-made and that have a topographic connection to a stream network. It excludes any longstanding canals and ditches or topographically eroded drainages

Slope: a topographic gradient on which intermittent water can be observed

Streambed: the area adjacent to an NHD stream line that is the topographic low

HGM Classification Key for Depressional Wetlands in the HPR

High Plains Region Hydrogeomorphic Key

1 Wetland is classified as Cowardin Palustrine 2
1 Wetland is not classified as Palustrine .... Stop here (this key is not applicable)
2 Wetland is detectable via remotely sensed data 3
2 Wetland is not detectable via remotely sensed data................................... ***Lost/Misclassified***
3 Wetland is associated with a natural, continuous NHD* stream or surrounding floodplain
....***Riverine* (5)**
3 Wetland is not associated with a natural, continuous NHD* stream 4
4 Wetland exists within a closed watershed .... ***Depressional* (9)**
4 Wetland exists along the edge of a lake or reservoir......................................***Lacustrine Fringe***

5 Wetland retains water due to landscape alteration (anthropogenic or beaver activity) 6
5 Wetland does not retain water due to landscape alteration 7
6 Wetland is excavated...Riverine Excavated
6 Wetland is diked .... Riverine Diked
7 Wetland is situated within current or historic streambed 8
7 Wetland is outside of streambed but within the floodplain......................... Riverine Floodplain
8 Wetland exists within streambed during low flow .... Riverine Streambed
8 Wetland is disconnected and was formed by streamflow at bend .... Riverine Oxbow

9 Wetland retains water due to landscape alteration 10
9 Wetland does not retain water due to landscape alteration 11
10 Wetland is excavated.. Depressional Excavated
10 Wetland is diked .... Depressional Diked
11 Wetland is situated within a drainage ....Depressional Draw
11 Wetland is not situated within a drainage...Playa Wetland

*NHD refers to the National Hydrography Database by the US Geological Survey

Literature Cited

Belden JB, Hanson, BR, McMurry, ST, Smith LM, Haukos DA (2012) Assessment of the effects of farming and conservation programs on pesticide deposition in High Plains wetlands. Environmental Science & Technology 46:3424-3432

Brinson MM (1993) A hydrogeomorphic classification for wetlands. U.S. Army Corps of Engineers, Washington DC

Cowardin LM, Carter V, Golet FC, LaRoe ET (1979) Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior Fish and Wildlife Service, Washington DC

Esri (2017) USA Counties. http://www.arcgis.com/home/item.html?id=48f9af87daa241c4b267c5931ad3b226

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Chapter 3: Models for Predicting Ecosystem Services

Ecosystem Service Models

SELECTED MODELS

The models included in this sampling manual have been developed through various projects in which wetland data were gathered to observe and predict ecosystem services. These models estimate services provided by playas and their associated vegetative buffers. All are based on field-collected data and indicate the condition of the wetland as a natural resource. A list of metrics required for applying models is included in Appendix A, while datasheets for all models are in Appendix B. At the time of writing this manual, the included models were deemed the most suitable in terms of applicability and ecosystem service estimations. These models will likely improve over time with increased application and ground truthing.

Application of these methods would expand the understanding of wetland condition by providing estimates of wetland function. The models in this manual could also be used to estimate service provisioning of playas within a current land use and to make a comparison to expected service provisioning under a potential future land use. This type of comparison could be used to estimate the effects of future conservation practices on ecosystem services provided by wetlands in the High Plains Region (HPR).

GENERAL PURPOSE USES

- Applicable for playa wetlands in the HPR.
- Utilizes remote sensing through maps, imagery and databases. A GIS is necessary for most of the metrics required to run these models.

RESTRICTIONS AND LIMITATIONS

Estimates: Users should note that these ecosystem service models are able to give general estimates based on a set of features specific to a playa and its surrounding landscape. Variables that are not considered could greatly affect the actual value compared to the model predicted value.

Subregions: The two HPR subregions of interest for this sampling manual are the Western High Plains (WHP) and the Rainwater Basin (RWB) (Figure 3-1). Models were built using data from playas in a specific subregions or areas of the HPR. For the most accurate estimates, each model should be applied within the appropriate subregion and area. Models are ideal for the subregions as listed below in Table 3-1.

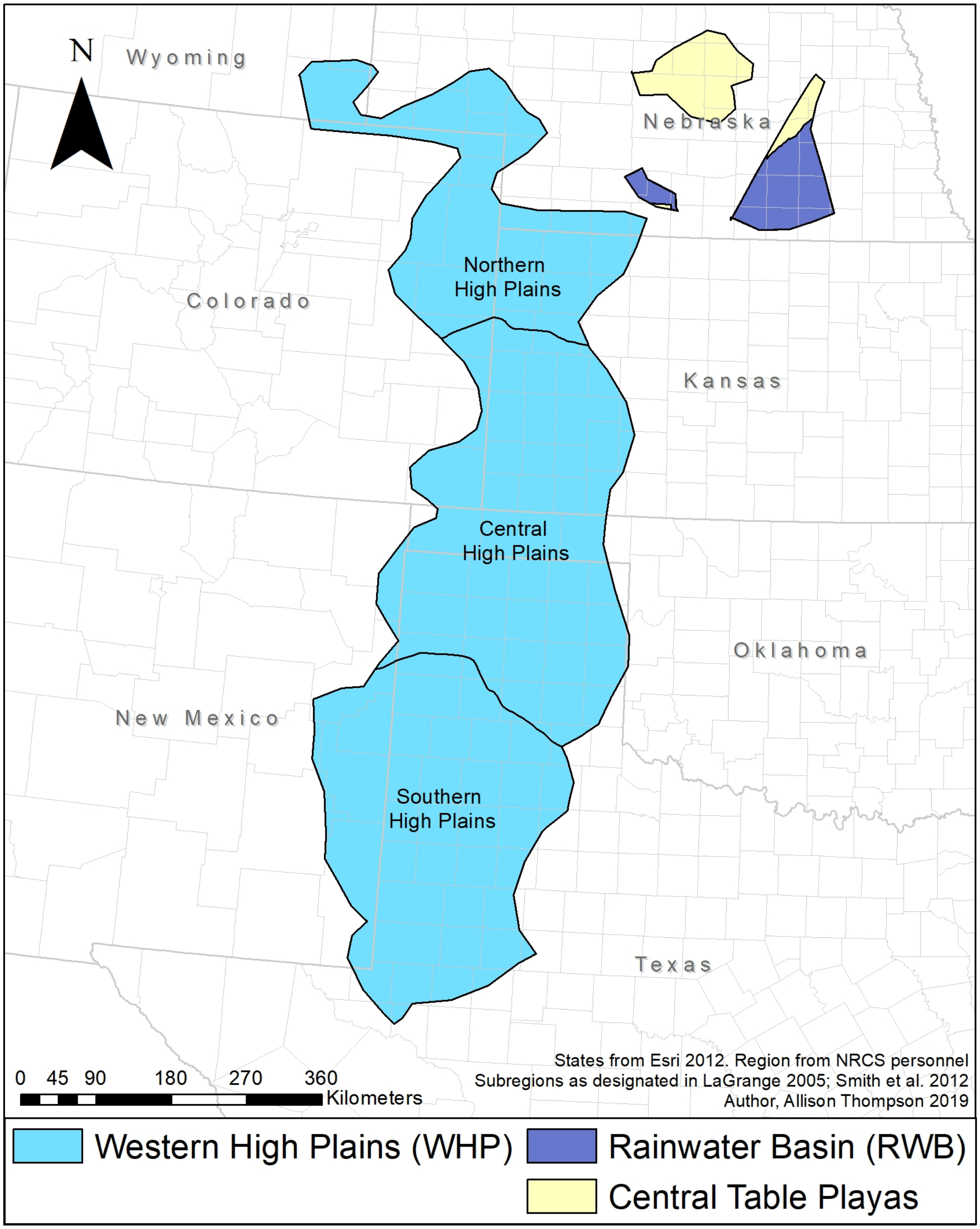

FIGURE 3-1 CONSERVATION EFFECTS ASSESSMENT PROJECT (CEAP) - WETLANDS HIGH PLAINS REGION (HPR) WITH SUBREGIONS AND PORTIONS SHOWN AS DESIGNATED BY LAGRANGE (2005) AND SMITH ET AL. (2012). DATA FROM ESRI (2017), RAINWATER BASIN JOINT VENTURE (2018) AND PERSONAL COMMUNICATION WITH WILLIAM EFFLAND (2017).

TABLE 3-1 SUBREGIONS AND PORTIONS WITHIN THE HPR RECOMMENDATIONS FOR MODELS FOR MOST ACCURATE PREDICTIONS.

SUBREGION/PORTION	**MODEL (NUMBER OF RANK)**
WESTERN HIGH PLAINS (WHP)	PESTICIDE RESIDUE (3) SOIL ORGANIC CARBON (7) PLANT SPECIES RICHNESS (8)
NORTHERN HIGH PLAINS (NHP) ONLY	GREENHOUSE GAS FLUX (6)
SOUTHERN HIGH PLAINS (SHP) ONLY	CONTAMINANT FILTRATION (1) CONTAMINANT CONCENTRATION (2) SEDIMENT DEPTH (4) FLOODWATER STORAGE (5) AMPHIBIAN SPECIES RICHNESS (10) POLLINATOR ABUNDANCE AND RICHNESS (11) AVIAN SPECIES RICHNESS AND WATERFOWL ABUNDANCE (12)
RAINWATER BASIN (RWB)	PESTICIDE RESIDUE (3) GREENHOUSE GAS FLUX (6) POLLINATOR ABUNDANCE, RICHNESS AND DIVERSITY (9)

Data Limitations: Some models were built from data within a given portion of the year or season. The model for Amphibian Species Richness was built using data when hydroperiod was between 18 and 453 days. Each model includes a description section which contains any limitations based on timing or range of values considered appropriate. It is recommended that for the most accurate estimate, a user does not apply the model outside of these recommended limitations.

Land Use Change: Care should be taken when seeking to estimate potential ecosystem services under future land-use conditions on a playa or a set of playas. Some of these models use a separate equation for predicting conditions under each available land use type. If future conditions are to be estimated using a different land use equation, all metrics should represent what would be present under those future conditions. If a vegetative reflectance value is required such as the Fraction of Photosynthetically Active Radiation or the Leaf Area Index, a value representing future conditions and not current conditions should be used. For example, if a user was interested in comparing the change in Greenhouse Gas Flux of a playa converted from cropland to CRP, two equations would need to be applied. First, the cropland equation would be used with the current cropland vegetative reflectance values. Secondly, the CRP equation would need to be applied using a representative CRP vegetative reflectance value to simulate what would be present if land use were converted. This representative value could be measured within a nearby CRP playa or could simply be an average CRP reflectance value within the local region.

GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING

DATA SOURCES

Users may select any appropriate data sources to measure variables needed to populate the models but selected sources should be of equal or greater quality when compared to those suggested by the authors. Topography, for example, may be available at higher resolutions or from more reliable documentation methods such as LiDAR derived Digital Elevation Models (DEM). The user however must keep in mind that if ecosystem services are to be compared across time or between potential land use changes, the same data sources should be used for accurate comparisons. For this reason, most of the data sources we have suggested are present across the entire HPR and are accessible to any user. The only exception to availability is that of Conservation Reserve Program (CRP) spatial data which is confidential and requires special permission to access. As stated in chapter 1, these data are not required for this sampling manual to be useful, but they would give a user the ability to identify a playa surrounded by CRP and to estimate service provisioning under those conditions. Users who do not have access to CRP data can estimate playa services under other detectable land use conditions, but could also simulate potential services if land use changed from one type to another. CRP land use can be simulated without access to the spatial data.

National Wetland Inventory (NWI): This dataset was established by USFWS and has identified all wetlands and waterbodies across the United States via aerial imagery. Polygons represent wetlands and other waterbodies by their Cowardin et al. (1979) classification. Data can be downloaded by state on the USFWS website https://www.fws.gov/wetlands/data/State-Downloads.html (U.S. Fish and Wildlife Service 2017).

USGS Topographic Maps: These maps were developed by USGS and can be downloaded directly from The National Map in geo.pdf format as a 7.5 minute quadrangle map. (https://viewer.nationalmap.gov/advanced-viewer/). A digital continuous version of the USGS developed map is also available through ESRI for use in the ArcGIS program at a scale up to 1:24,000 (http://www.arcgis.com/home/item.html?id=99cd5fbd98934028802b4f797c4b1732).

CropScape: This dataset was created by the USDA National Agricultural Statistics Service (NASS) and provides estimates on land use regarding crops and crop types during each growing season nationwide. CropScape includes 132 categories for land cover, each with a designated numeric code. Data is organized in a 30 x 30 m raster grid and is downloadable from the NASS website (https://nassgeodata.gmu.edu/CropScape/). The main land use types identified from these data are croplands, fallow crop and native grass. This dataset does not include a true native grassland category but general grassland can be used to make model estimates.

Conservation Reserve Program (CRP): For users with access to these data, land use can be identified from spatial data.

Wetland Reserve Program/Wetland Reserve Easement (WRP/WRE): This dataset provides general locations of easements and can be used to determine land use on Rainwater Basin playas in Nebraska. Data can be accessed from the Geospatial Data Gateway at https://datagateway.nrcs.usda.gov/.

Reference Wetland: Designated as least disturbed in the Rainwater Basin, these wetland locations can be identified through contact with the Nebraska Game and Parks Commission (NGPC).

Land use types for predictive models should be matched with land cover categories according to table 3-2:

TABLE 3-2. LAND USE EQUIVALENT FOR DATA SOURCES LISTED.

MODEL LAND USE	**LAND COVER DATA SOURCE**
CROPLAND/AGRICULTURE CURRENTLY CULTIVATED	CROPSCAPE: ANY CROP LAND COVER, ALL BUT NON-CROP (I.E. FALLOW, FOREST, DEVELOPED, WATER, BARREN)
FALLOW CROP PREVIOUSLY CULTIVATED BUT UNMANAGED	CROPSCAPE: FALLOW/IDLE *61 – FALLOW/IDLE CROPLAND*
NATIVE GRASSLAND NON-CULTIVATED	CROPSCAPE: GRASS OR PASTURE *176 – GRASSLAND/PASTURE*
CRP CONSERVATION RESERVE PROGRAM	FOR USERS WITH ACCESS TO CONFIDENTIAL DATA
WRP/WRE WETLANDS RESERVE PROGRAM/WETLANDS RESERVE EASEMENT	GEOSPATIAL DATA GATEWAY NRCS CONSERVATION EASEMENT DATASET
REFERENCE WETLAND AS DESIGNATED BY NEBRASKA GAME AND PARKS COMMISSION	DETERMINED THROUGH CONTACT WITH THE NEBRASKA GAME AND PARKS COMMISSION (NGPC)

Satellite Imagery: recent imagery can be accessed through Earth Explorer where Landsat 8 scenes can be downloaded for the location of interest (https://earthexplorer.usgs.gov/). Smaller features such as constructed dikes, pits and drainage canals can be detected using this imagery. Historical Landsat imagery is also available.

OTHER DATASETS

SSURGO: is the Soil Survey Geographic Database which contains information from the National Cooperative Soil Survey. This survey has collected field data and mapped soil types in the United States for almost a century. Data can be accessed through the Web Soil Survey, and many different soil characteristic data are available (https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

MODIS: is the Moderate Resolution Imaging Spectroradiometer. This is a sensor that is onboard the Terra and Aqua Satellites run and monitored by the National Aeronautics and Space Administration (NASA). This sensor is able to gather images from many different spectral bands and is capable of determining vegetative condition through Fraction of Photosynthetically Active Radiation (FPAR) and Leaf Area Index (LAI). Data can be accessed from NASA's Earth Data web page (https://search.earthdata.nasa.gov/search).

COORDINATE SYSTEMS

For observing maps and other spatial data, the authors recommend 'NAD_1983_Albers' as the coordinate system. This system is used by the National Wetlands Inventory (NWI) and limits area distortions across the extent of the United States (for more information see https://www.fws.gov/wetlands/data/Projection.html). When using a GIS to observe numerous datasets which may include vectors and rasters, the data frame and all data layers should have matching geographic and projected coordinate systems. This prevents measurement and location errors between data layers. Transformations between coordinate systems may be required.

- Coordinate System: North American Datum 1983 Albers (NAD 1983 Albers)
    - Datum: North American 1983 (NAD 1983)
    - Geographic Coordinate System: GCS North American 1983
    - Projected Coordinate System: Albers Conical Equal Area

ARCMAP INSTRUCTIONS

Geographic Information System (GIS) instructions are included throughout this manual for ESRI ArcMap 10.4. The authors sought to provide a straightforward method with detailed instructions for this commonly used system. While instructions provided here are specific to ArcMap, other geographic information systems can be used. As stated above, datasets and remote sensing tools and programs with equal or greater reliability are encouraged for use with this manual.

Ecosystem Service Models

1. Percent Contaminant Filtration (%)

PERCENT REMOVAL BY VEGETATIVE BUFFER TYPE

Playas accumulate contaminants from the surrounding upland through runoff. For a playa in a cultivated watershed, a buffer of vegetation along the wetland edge is capable of filtration by trapping a certain percentage of runoff contaminants and withholding those from the wetland basin. The filtration occurring in a vegetative buffer depends on the type of vegetation present. The percent of an upland contaminant removed by a buffer can be estimated when the vegetative type is identified using land cover data. Vegetative buffer type includes Conservation Reserve Program (CRP), fallow crop, and native grassland. If no buffer is present between cultivated crops and playa edge, filtration is considered to be 0%. Once the vegetative buffer is identified, a maximum filtration percent can be selected based on the contaminant of interest utilizing Table 3-1 below (Haukos et al. 2016).

Sub-Region(s): Southern High Plains (SHP). Not recommended for use in other portions of the Western High Plains (WHP) or the Nebraska Rainwater Basin (RWB) playas (Figure 3-1).

Note: Estimation for Percent Contaminant Filtration (Model 1) was included here along with wetland Contaminant Concentration (Model 2). Although these estimations both predict contaminants, they answer slightly different questions. Percent filtration can be used to determine the effectiveness of a vegetative buffer based on its land-use type. Contaminant concentration determines the amount of contaminants estimated to be present within the water moving into the wetland.

COMPONENTS

- Metric A: Vegetative Buffer Type
- Land-use data
- Table 3-3: Contaminant Filtration by Buffer Type

METHODS

1. **Determine Vegetative Buffer Type (Metric A)**
   Instructions
   1.1. Identify the vegetative buffer by observing a land-use data. Buffer is determined by the land use surrounding >50% the wetland edge that is not classified as cropland.
   1.2. Can be any of the following non-crop vegetation type. Data source in parenthesis (Table 3-2).
      - **Fallow:** unmanaged, previously cultivated (CropScape: 61 – Fallow/Idle)
      - **Native Grassland**: rangeland/grazing land (CropScape: 176 – Grassland/Pasture)
      - **CRP**: Conservation Reserve Program (CRP spatial data)
      - **None** = no vegetative buffer, no filtration
2. **Select average percent contaminant filtration Table 3-3**

Instructions

2.1 Use table 3-3 and select contaminant of interest.

Table 3-3. Percent (±SE) contaminant removal carried out by vegetative buffer within a cropland watershed. Removal values based on vegetation type. From haukos et al. (2016).

Contaminant	**Vegetative Buffer Type**					
	CRP	(SE)	Fallow	(SE)	Native Grassland	(SE)
Total Suspended Solids (TSS) (%)	85.43	(6.16)	79.76	(4.91)	83.44	(3.84)
Total Dissolved Solids (TDS) (%)	57.53	(8.29)	57.62	(6.61)	58.85	(5.17)
Aluminum (Al) (%)	69.71	(8.14)	74.11	(6.65)	77.59	(5.54)
Arsenic (As) (%)	81.31	(8.81)	84.24	(7.20)	74.5	(5.99)
Barium (Ba) (%)	63.73	(8.47)	69.93	(6.92)	79.79	(5.75)
Calcium (Ca) (%)	58.55	(9.86)	62.7	(8.05)	67.17	(6.70)
Chromium (Cr) (%)	98.93	(11.21)	71.54	(9.15)	92.94	(7.62)
Copper (Cu) (%)	68.65	(8.51)	64.35	(6.95)	82.67	(5.78)
Iron (Fe) (%)	71.61	(7.62)	74.93	(6.22)	81.83	(5.18)
Potassium (K) (%)	64.25	(7.81)	60.92	(6.38)	66.89	(5.31)
Magnesium (Mg) (%)	72.97	(8.00)	68.56	(6.53)	69.93	(5.44)
Manganese (Mn) (%)	72.45	(7.54)	74.81	(6.12)	83.64	(5.12)
Nitrogen (N) (%)	85.65	(10.45)	77.96	(8.34)	76.46	(6.52)
Sodium (Na) (%)	58.63	(9.51)	57.38	(7.77)	54.66	(6.46)
Phosphorus (P) (%)	72.04	(8.69)	59.43	(7.09)	76.13	(5.90)
Strontium (Sr) (%)	50.01	(9.97)	65.78	(8.41)	67.21	(6.77)
Vanadium (V) (%)	89.95	(10.11)	77.81	(8.25)	82.3	(6.87)
Zinc (Zn) (%)	60.6	(7.67)	65.64	(6.26)	76.69	(5.21)

2. Contaminant Concentration (ppm)

CONCENTRATION IN RUNOFF BY AVERAGE VEGETATIVE BUFFER WIDTH

Contaminants from the upland are carried into the wetland basin by runoff. Although an established vegetative buffer is capable of filtering a percentage of runoff contaminants, most contaminant types still occur at some level in wetlands with cultivated watersheds. The concentration of contaminants found in the runoff flowing into a playa is related to the width of the vegetative buffer surrounding the playa edge. An increased distance between the cultivated edge and the playa basin causes a decrease in contaminant concentration. The mean width of a non-crop vegetative buffer up to 60 m can be used to estimate the mean concentrations of widespread contaminants within the runoff moving into a wetland. Vegetative buffers exceeding 60 m have not been tested for this model but are understood to provide negligible improvements in contaminant removal (Haukos et al. 2016).

Subregion(s): developed for the SHP and not recommended for use in other portions of the WHP or the RWB (Figure 3-1).

COMPONENTS

- Metric B: Mean Vegetative Buffer Width (m)
- Land-use data
- Table 3-4: Contaminant Concentrations

METHODS

1. **Calculate Mean Vegetative Buffer Width (Metric B)**
   Instructions
   1.1. Determine playa centroid.

   ARCMAP INSTRUCTIONS

   Make data fields
   - *Open the wetland shapefile Attribute Table. Select Table Options > Add Field. Make a field labeled 'Latitude' with the field type set as double*
   - *Repeat above steps for a field labeled 'Longitude'*

   Calculate Latitude and Longitude values
   - *Begin an editing session for the playa shapefile*
   - *Right click the 'Latitude' field and select 'Calculate Geometry'. In this dialog box, select 'Y Coordinate of Centroid' from the property drop down. Units should be selected as 'Decimal Degrees' from the drop down.*
   - *Repeat above for 'Longitude' field using the 'X Coordinate of Centroid'*

   Export coordinates to a table
   - *In the Attribute Table, select Table Options > Export*
   - *Select the save location and when prompted, add the table to the current map*

   Display coordinates
   - *Right click added table and choose "display xy coordinates"*
   - *Set XField as 'Longitude' and YField as 'Latitude'*
   - *Right click points layer and export as shapefile to location of choice*

1.2. Select points on playa edge corresponding with the four cardinal directions from centroid.

ARCMAP INSTRUCTIONS

- ***Add 4 edge points to shapefile***
  - *Add the coordinate points shapefile to the current map document*
  - *Begin an editing session for the point shapefile*
  - *Use the 'Create Features" window and select the shapefile. Use 'Construction Tools' to add points to the shapefile. Use 'Point at end of line' tool to make points on playa edge. Direction from centroid point should be 0°, 90°, 180°, and 270° corresponding with the 4 cardinal directions.*
  - *Attribute table can be edited to label each point for each associated cardinal direction.*

1.3. From each edge point, measure and record the vegetative buffer width up to 60 m. Measurement should be taken at an approximately 90 ° angle from playa edge to measure width.

1.4. Identify land use as any of the following non-crop vegetation type from land-use data. Data source in parenthesis (Table 3-2).

- **Fallow:** unmanaged, previously cultivated (CropScape: 61 – Fallow/Idle)
- **Native Grassland**: rangeland/grazing land (CropScape: 176 – Grassland/Pasture)
- **CRP**: Conservation Reserve Program (CRP spatial data)

1.5. Calculate the mean vegetative buffer width using the measurements from all four directions.

2. Select average contaminant concentration (ppm)

2.1. Use table 3-4 to select contaminant of interest.

2.2. Round the mean buffer width to the nearest 10 and select concentration for contaminant of interest.

Table 3-4. Mean (±SE) concentrations (ppm) of 19 contaminants found in runoff flowing into playas at increasing vegetative buffer widths. From haukos et al. (2016).

Contaminant	Buffer (m)	Mean (ppm)	SE	Contaminant	Buffer (m)	Mean (ppm)	SE
Aluminum (Al)	0	168.5	23.9	Arsenic (As)	0	0.218	0.0275
	10	105.82	17.176		10	0.1359	0.0215
	20	69.857	14.039		20	0.0912	0.0188
	30	54.374	11.966		30	0.0723	0.0156
	40	46.923	11.629		40	0.0643	0.0162
	50	44.595	13.133		50	0.0555	0.016
	60	45.899	20.774		60	0.0575	0.0246
Barium (Ba)	0	0.6636	0.0768	Calcium (Ca)	0	66.791	18.747
	10	0.4589	0.0593		10	22.676	3.2419
	20	0.3138	0.0484		20	16.793	2.4937
	30	0.2491	0.0439		30	15.127	2.5467
	40	0.2157	0.0483		40	11.179	1.5925
	50	0.2118	0.0542		50	8.4427	1.6784
	60	0.205	0.0645		60	13.014	5.2814
CHROMIUM (CR)	0	0.1452	0.0418	Copper (Cu)	0	0.1936	0.1281
	10	0.0674	0.0122		10	0.0493	0.007356
	20	0.0442	0.0104		20	0.0327	0.005161
	30	0.0309	8.35E-03		30	0.025	0.003989
	40	0.0307	8.86E-03		40	0.0221	0.004591
	50	0.0273	0.0102		50	0.02	0.004671
	60	0.0275	0.0128		60	0.0175	0.006748
Iron (Fe)	0	101.99	15.005	Potassium (K)	0	42.36	5.4731
	10	64.23	10.582		10	29.008	2.9826
	20	40.975	7.9188		20	19.606	2.3005
	30	31.506	6.6278		30	17.454	2.2876
	40	28.186	6.9828		40	15.169	2.6746
	50	26.699	8.034		50	12.425	2.7249
	60	27.207	12.058		60	14.52	4.2032
Magnesium (Mg)	0	32.521	9.0387	Manganese (Mn)	0	1.4572	0.2053
	10	16.388	2.1295		10	0.9444	0.1621
	20	10.67	1.555		20	0.6385	0.1138
	30	8.5486	1.5101		30	0.4682	0.1057
	40	7.9557	1.7998		40	0.4307	0.1114
	50	6.75	1.8378		50	0.3318	0.0697
	60	7.9787	2.8199		60	0.4013	0.1568

Table 3-4. Continued.

Contaminant	Buffer (m)	Mean (ppm)	SE	Contaminant	Buffer (m)	Mean (ppm)	SE
Sodium (Na)	0	39.209	35.808	Nitrogen (N)	0	0.272	0.1716
	10	2.2037	0.3591		10	0.0737	0.009625
	20	1.6469	0.2664		20	0.0608	0.007584
	30	1.3859	0.2701		30	0.0491	0.005342
	40	1.3493	0.3214		40	0.04	0.006202
	50	1.1082	0.336		50	0.0327	0.007273
	60	1.0475	0.3601		60	0.0363	0.0116
Nitrate_p	0	4.1667	1.2052	Phosphorous (P)	0	2.0396	0.2101
	10	3.2844	0.8423		10	1.4426	0.1596
	20	2.3781	0.7942		20	1.08	0.1509
	30	1.3133	0.3859		30	0.9241	0.1417
	40	0.955	0.3957		40	0.8629	0.1556
	50	0.4	0.1187		50	0.7273	0.1697
	60	0.4818	0.1667		60	0.6837	0.1824
Total Dissolved Solids (TDS)	0	0.2659	0.1036	Total Suspended Solids (TSS)	0	2.7231	0.5349
	10	0.1111	0.0145		10	1.7194	0.3595
	20	0.0737	8.19E-03		20	1.0846	0.2339
	30	0.0703	0.0119		30	0.7682	0.2107
	40	0.0666	0.0164		40	0.6345	0.2448
	50	0.0438	7.43E-03		50	0.6218	0.2588
	60	0.0457	9.18E-03		60	0.8159	0.3379
Vanadium (V)	0	0.1584	0.0296	Zinc (Zn)	0	0.8736	0.4365
	10	0.1148	0.0205		10	0.3544	0.0371
	20	0.1208	0.0267		20	0.2869	0.035
	30	0.0636	0.0134		30	0.2082	0.0214
	40	0.0669	0.0223		40	0.19	0.0242
	50	0.0909	0.0283		50	0.2	0.0425
	60	0.1288	0.0423		60	0.1763	0.0304

3. Pesticide Residue (µg/kg)

CONCENTRATION IN PLAYA SEDIMENTS BY LOCATION AND LAND USE

The concentrations of pesticide residue in playa sediments vary depending on surrounding land use and subregion. In the High Plains, there are three areas that exhibit slight differences: the southern playas, northern playas and those in the RWB in Nebraska. Discrete values can be estimated for a playa of interest based on subregion and surrounding land use (Kensinger et al. 2014).

Subregion(s): developed for both WHP and RWB subregions (Figures 3-2 and 3-3). Conservation programs differ between subregions.

COMPONENTS

- Metric C: Dominant Surrounding Land Use (500 m)
- Land-use data
- Table 3-5: Pesticide Concentrations

METHODS

1. **Determine playa subregion**
   Instructions
   1.1. Identify the state/area that the playa of interest exists within (Figure 3-2).
      - **Northern Playas**: Kansas, Colorado, Western Nebraska
      - **Southern Playas**: Oklahoma, New Mexico, Texas
      - **Rainwater Basin**: South Central Nebraska (Figure 3-3)

2. **Determine Dominant Land Use (Metric C)**
   Instructions
   1.1. Establish a 500 m radius buffer around playa shape.
   1.2. Within the land-use buffer, measure or visually inspect the categories displayed in the land-use data.
   1.3. Calculate (or estimate if obvious) land-use type covering >50% of the area within the buffer. Data Source in parenthesis (Table 3-2).
      - **Cropland**: in production (CropScape: any crop type)
      - **Native Prairie:** rangeland/grazing land (CropScape: 176 – Grassland/Pasture)
      - **CRP**: Conservation Reserve Program (CRP spatial data)
      - **WRP/WRE:** Wetland Reserve Program or Wetland Reserve Easement (Geospatial Data Gateway)
      - **Reference:** least disturbed wetland (Nebraska Game and Parks Commission)

3. **Select average contaminant concentration (ug/kg)**
   Instructions
   3.1. In Table 3-5, select the appropriate heading based on subregion.
   3.2. Select the column which corresponds with the contaminant of interest.
   3.3. Select the row based on dominant land use and identify the corresponding concentration value.

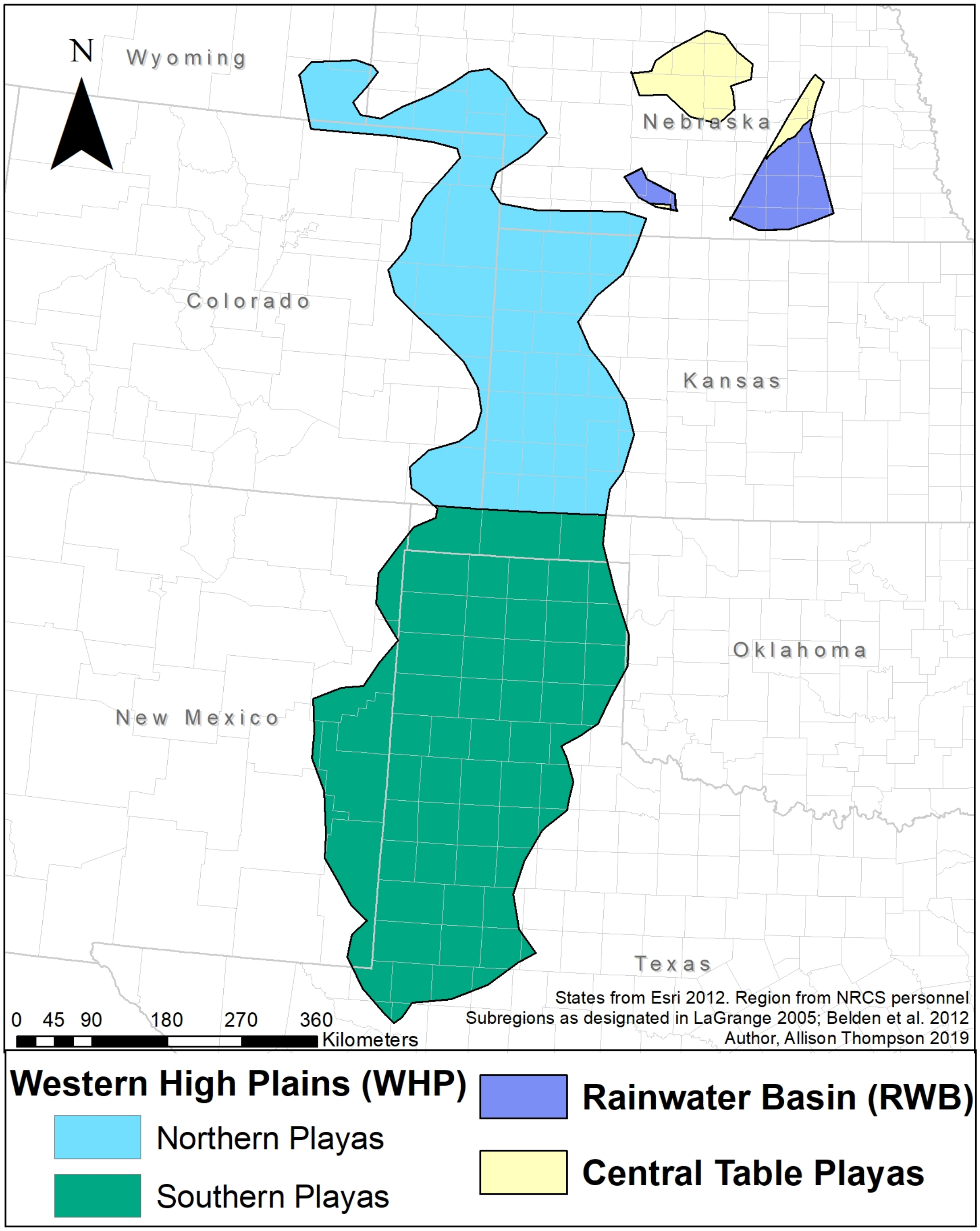

Figure 3-2 Conservation Effects Assessment Project (CEAP) - Wetlands High Plains Region (HPR) with subregions and playa groups shown as designated by LaGrange (2005) and Belden et al. (2012). Data from ESRI (2017), Rainwater Basin Joint Venture (2018) and personal communication with William Effland (2017).

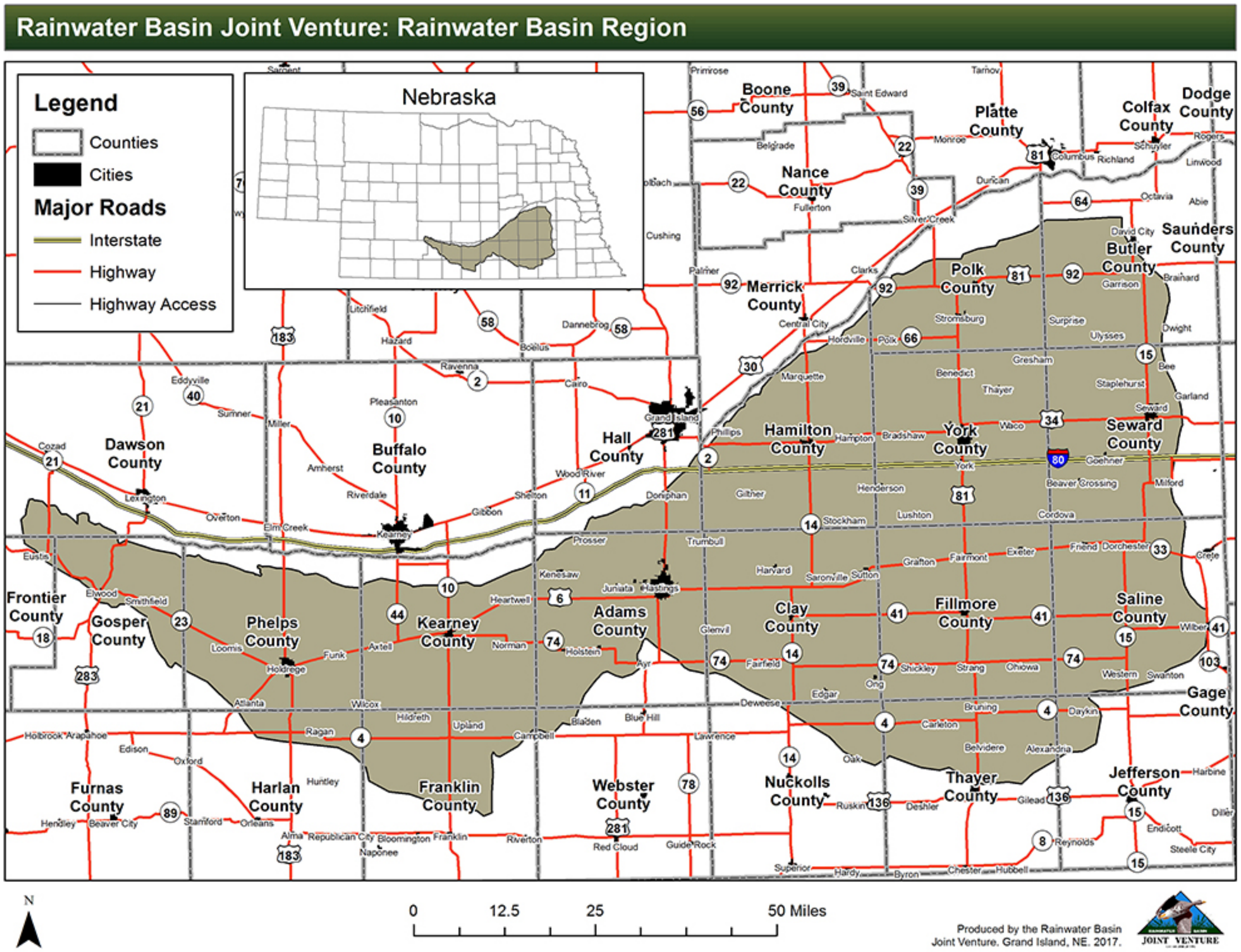

FIGURE 3-3. RAINWATER BASIN (RWB) SUBREGION OF NEBRASKA. FROM RAINWATER BASIN JOINT VENTURE (2018).

TABLE 3-5. MEAN (±SE) PESTICIDE RESIDUE CONCENTRATIONS (μG/KG) FOR COMMON PESTICIDES FOUND IN PLAYA SEDIMENTS ACROSS THREE DIFFERENT PORTIONS OF THE HPR. TABLE MODIFIED FROM KENSINGER ET AL. (2014).

Northern Playas	***Acetochlor***	***(SE)***	***Atrazine***	***(SE)***	***S-metolachlor***	***(SE)***	***Trifluralin***	***(SE)***
Cropland	0.11	0.11	23.78	13.84	10.36	7.36	0.10	0.07
Native prairie	0.23	0.05	0.42	0.09	0.42	0.09	0.18	0.04
CRP	0.00	0.00	0.67	0.15	0.00	0.00	0.05	0.01
Southern Playas	***Acetochlor***	***(SE)***	***Pendimethalin***	***(SE)***	***S-metolachlor***	***(SE)***	***Trifluralin***	***(SE)***
Cropland	1.64	0.72	15.12	14.28	2.35	2.13	4.87	1.91
Native prairie	1.13	0.61	0.00	0.00	0.23	0.23	0.25	0.12
CRP	0.18	0.03	0.29	0.04	0.00	0.00	0.71	0.10
Rainwater Basin Playas	***Acetochlor***	***(SE)***	***Atrazine***	***(SE)***	***S-metolachlor***	***(SE)***	***Trifluralin***	***(SE)***
Cropland	1.26	1.26	86.08	80.33	3.61	1.68	0.19	0.10
Reference	0.00	0.00	4.47	3.30	0.68	0.26	0.42	0.15
WRP(ACEP)	3.61	3.03	1.48	0.64	0.42	0.17	0.13	0.09

4. Sediment Depth (cm)

PLAYA BASIN BY PERCENT CROP IN WATERSHED

There is a strong relationship between playa sediment accumulation and land use within the watershed. Sediments depths increase within a playa basin when soil disturbance occurs in the watershed and increased agricultural production causes greater sediment accumulation. Sediment depths can be estimated based on the percent cropland within the watershed using equation 3-2 (McMurry and Smith 2018).

Subregion(s): this predictive model was developed for the SHP and not recommended for use in other portions of the WHP or the RWB (Figure 3-1).

Note: to determine Metric D: Percent Crop in Watershed, users must delineate a playa watershed within the local area. USGS watershed boundaries are not suitable for use here as those boundaries were developed in conjunction with stream network locations and playa watersheds are closed and are disconnected from stream systems.

COMPONENTS

- Metric D: Percent Crop in Watershed
- Land-use dataset
- Equations 3-1 and 3-2

METHODS

1. **Determine percent crop within the watershed (Metric D)**
   Instructions
   1.1. Delineate the playa watershed using a topographic map in a GIS
   ArcMap Instructions
      - Open a spatially referenced topographic map as a basemap with the playa of interest. Projections for data frame, playa polygon and topo map should be the same.
      - Create a new feature class and begin an editing session. In the Create Features window use the Construction Tool to make a polygon by placing points on all high terrain locations surrounding the playa. For more detailed instructions on watershed delineation see https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_014819.pdf
      - Save the polygon and label the watershed to correspond with the playa label.

   1.2. Calculate the total area within the watershed
   1.3. Calculate the area within the watershed that is identified as crop or agriculture using the land-use dataset of choice. Data source in parenthesis (Table 3-2).
      - **Cropland**: in production (CropScape: any crop type)

   1.4. Determine the percent of the total area that is identified as crop or agriculture. This can be done by using equation 3-1.

EQUATION 3-1

$$percent.crop = \frac{crop.area}{total.area} * 100$$

2. Solve for sediment depth (cm) using percent crop

Instructions

2.1. Use percent crop value from the method listed above and apply to equation 3-2 to determine sediment depth (cm).

EQUATION 3-2

$$sediment.depth = (0.44987 + 0.4457 * percent.crop)$$

5. Floodwater Storage (m^3)

EQUATIONS USING ORIGINAL VOLUME AND VOLUME LOSS

Precipitation from a playa's watershed can flow into the basin and be stored as floodwater. Sediments also flow into the basin and are deposited there, decreasing the basin depth and causing reduction in floodwater storage volume. Increase in sediment depth is related to land disturbance in the watershed and causes a predictable change in the volume of floodwater that can be stored. The relationship between playa area and original playa volume before sedimentation is quantified in the *Original Volume* equation (Table 3-4). The relationship between percent volume loss and sediment depth is quantified in the *Percent Lost* equation (Table 3-4). These values are both used to estimate volume of current potential floodwater storage for a playa of interest (McMurry and Smith 2018).

Subregion(s): this predictive model was developed for the SHP and not recommended for use in other portions of the WHP or the RWB (Figure 3-1).

Note: Floodwater estimates can be negative when sediments have completely filled the playa basin and begin to fill the surrounding upland. Users may consider a negative floodwater estimate as 0 depending on the goal of their objectives.

COMPONENTS

- Metric E: Playa Area (ha)
- Playa Model 4: Sediment Depth
- Table 3-6: Volume equations

METHODS

1. **Determine Playa Area (Metric E)**
   Instructions
   3.1. Calculate playa area (ha) within the shapefile using a GIS

2. **Calculate Floodwater Storage based on original volume (OVol) and volume loss (LVol)**
   Instructions
   2.1. Determine Original Volume (m^3) using playa area (ha) and the equation (Table 3-6).
   2.2. Determine Percent Lost using sediment depth (cm) from Model 4 and the given equation (Table 3-6).
   2.3. Calculate Total Volume Lost (m^3) using original volume (m^3) and percent volume lost along with the given equation (Table 3-6).
   2.4. Calculate current floodwater storage (m^3) using original volume (m^3) and volume lost (m^3) along with the given equation (Table 3-6).

TABLE 3-6. EQUATIONS TO DETERMINE PLAYA ORIGINAL VOLUME (M^3), PERCENT VOLUME LOST (%), TOTAL VOLUME LOST (M^3) AND CURRENT FLOODWATER STORAGE (M^3). MODIFIED FROM MCMURRY AND SMITH (2018).

Model Name	***Equation***	***Predictors***
Original Volume (m^3)	OVol = 13868.5182 + 740.5821*area + 135.0543*area^2	area (ha)
Percent Lost (%)	%Lost = 20.9841 + 2.4595*sed.depth	sed.depth (cm)
Total Volume Lost (m^3)	LVol = OVol*(%Lost / 100)	OVol (m^3) %Lost (%)
Floodwater Storage (m^3)	FwSt = OVol – LVol	OVol (m^3) LVol ($m^{3)}$)

6. Greenhouse Gas Flux (g C/ha/day)

REGRESSION USING MODIS VALUES

Greenhouse gases include carbon dioxide, methane, and nitrogen dioxide. A playa can be both a source and sink for greenhouse gasses depending on the wetland condition and water level at a given time. Net greenhouse gas (GHG) flux is defined here as the carbon dioxide equivalent for the sum of all emissions and absorptions of the three most common greenhouse gasses (CO_2+CH_4+N_2O). This metric indicates the overall exchange of these gasses occurring in wetland. GHG flux differs across playas in varying land-use types and is related to remotely sensed vegetation metrics. Fraction of Photosynthetically Active Radiation (FPAR) represents the amount of radiation absorbed by green vegetation and Leaf Area Index (LAI) represents green leaf area per unit ground area. These values relate to GHG flux differently within different regions of the High Plains. Remotely sensed measurements for both are provided by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) (Zhuoqing et al. 2016a).

Subregion(s): developed for the Northern High Plains (NHP) portion of the WHP as well as the RWB. Not recommended for use in other portions of the WHP (Figures 3-1 and 3-3).

Limitations: Data used to build this model were sampled from the months of April to October. Estimates are considered most accurate for predicting GHG values during this time. To predict service provisioning based on future land use conditions, reflectance values representing that type should be used.

COMPONENTS

- Metric C: Dominant Land Use (500 m)
- Land-use data
- Metric F: Moderate Resolution Imaging Spectroradiometer (MODIS) Values
- Table 3-7: GHG Flux Equations

METHODS

1. **Determine High Plains Subregion**
   Instructions
   1.1. Identify the subregion for the playa of interest (Figure 3-1, Figure 3-3).
   - **Western High Plains (WHP)**: Western half of Nebraska and all other HPR states
   - **Rainwater Basin (RWB)**: South Central Nebraska

   1.2. Use sub region to select necessary section of Table 3-7.

2. **Determine Dominant Land Use (Metric C)**
   Instructions
   2.1. Establish a 500 m radius buffer around playa shape.
   2.2. Within the land-use buffer, measure or visually inspect the categories displayed in the land-use dataset and conservation program spatial data.
   2.3. Calculate (or estimate if obvious) land-use type covering >50% of the area within the buffer. Data source in parenthesis (Table 3-2).
   - **Cropland**: in production (CropScape: any crop type)
   - **Native Prairie:** rangeland/grazing land (176 – Grassland/Pasture)

- **CRP**: Conservation Reserve Program (CRP spatial data)
- **WRP/WRE:** Wetland Reserve Program or Wetland Reserve Easement (Geospatial Data Gateway)
- **Reference**: least disturbed wetland (Nebraska Game and Parks Commission)

2.4 From dominant land use, select necessary GHG equation from Table 3-6.

3. **Determine appropriate MODIS values (Metric F)**

Instructions

3.1. Go to https://search.earthdata.nasa.gov/search and download <MODIS/Terra Leaf Area Index/FPAR 8-day L4 Global 500m SIN Grid> granule for location of interest.

3.2. View the raster in a GIS and read values of the pixel at the playa center.

ArcMap Instructions

- MODIS User Guide for reference
- https://lpdaac.usgs.gov/documents/2/mod15_user_guide.pdf
- Upload rasters into ArcMap along with a playa shapefile
- Re-project LAI and FPAR rasters from sinusoidal to projection of choice (new projection should match data frame and playa shapefile)
- Determine the raster cell value within the playa basin
  - LAI (Leaf Area Index)
    - Range: 0-100
    - Scale factor: multiply cell value by: 0.1
  - FPAR (Fraction of Photosynthetically Active Radiation)
    - Range: 0-100
    - Scale factor: multiply cell value by 0.01

TABLE 3-7. GREENHOUSE GAS FLUX (G C/HA/DAY) ESTIMATES FOR PLAYAS BASED ON SUBREGION, DOMINANT LAND USE AND REMOTELY SENSED VEGETATION FEATURES. TABLE MODIFIED FROM ZHUOQING ET AL. (2016A).

Rainwater Basin Land Use	***Rainwater Basin GHG Flux (g C/ha/day)***	***Predictors***
Agriculture	Ag_RWB_GHG = 196485.656 * POWER(FPAR,1.357)	FPAR
Reference	Ref_RWB_GHG = 171901.578 * POWER(FPAR,1.222)	FPAR
WRP/WRE	WRP_RWB_GHG = 82717.861 – 13595.894/FPAR	FPAR
Western High Plains Land Use	***Western High Plains GHG Flux (g C/ha/day)***	***Predictors***
Agriculture	Ag_WHP_GHG = EXP(11.568 – 0.538/FPAR)	FPAR
Native Grass	NG_WHP_GHG = EXP(11.118 – 0.27/LAI)	LAI
CRP	CRP_WHP_GHG = EXP(11.447 – 0.603/FPAR)	FPAR

7. Soil Organic Carbon (kg/m^2)

REGRESSION USING SSURGO METRICS

The ability of a wetland to sequester carbon is related to a host of variables including geographic features, vegetative communities and water presence. Soil organic carbon (SOC) values at a 0–50 cm depth within a playa basin can be estimated for three separate land uses across the WHP. This estimation uses equations developed with SSURGO values and a mean Soil Adjusted Vegetative Index (SAVI) for the year. Estimated SOC is closely related to dominant land use. Once an equation is selected, numerous predictors must be determined from the SSURGO database and remotely sensed imagery to be used in the given equations (Zhuoqing et al. 2016b).

Subregion(s): this predictive model was developed for the WHP and not recommended for use in RWB playas (Figure 3-1).

Limitations: In the NHP, Agriculture and CRP playas with greater than 85% sand in the Web Soil Survey cannot accurately be predicted using the following models. Values for percent SOC should be used and can be converted to kg/m^2 using bulk density from the Web Soil Survey, sample depth and a given area.

COMPONENTS

- Metric C: Dominant Surrounding Land Use (500m)
- Land-use data
- Metric G: Soil Survey Geographic Database (SSURGO) Predictors
    - websoilsurvey.gov
- Metric H: Soil Adjusted Vegetative Index (SAVI)
    - NIR Satellite Imagery Band and RED Satellite Imagery Band
    - Or Landsat 8 Spectral Reflectance
- Table 3-8 through 3-10: SSURGO metrics for estimating soil organic carbon

METHODS

1. Determine Dominant Land Use (Metric C)

Instructions

1.1. Establish a 500 m radius buffer around playa shape.

1.2. Within the land-use buffer, measure or visually inspect the categories displayed in the land-use dataset and conservation program spatial data.

1.3. Calculate (or estimate if obvious) land-use type covering >50% of the area within the buffer. Data source in parenthesis (Table 3-2).

- **Agriculture**: in production (CropScape: any crop type)
- **Native Grass:** rangeland/grazing land (CropScape: 176 – Grassland/Pasture)
- **CRP:** Conservation Reserve Program (CRP spatial data)

1.4. Use Dominant Land Use.

Use dominant land use to select necessary SOC equation from Table 3-7

2. SSURGO feature values for playa points of interest (Metric G)

Instructions

2.1. Determine playa centroid coordinates.

ARCMAP INSTRUCTIONS

Make data fields

- Open the wetland shapefile Attribute Table. Select Table Options > Add Field. Make a field labeled 'Latitude' with the field type set as double
- Repeat above steps for a field labeled 'Longitude'

Calculate Latitude and Longitude values

- Begin an editing session for the playa shapefile
- Right click the 'Latitude' field and select 'Calculate Geometry'. In this dialog box, select 'Y Coordinate of Centroid' from the property drop down. Units should be selected as 'Decimal Degrees' from the drop down.
- Repeat above for 'Longitude' field using the 'X Coordinate of Centroid'

Export coordinates to a table

- In the Attribute Table, select Table Options > Export
- Select the save location and when prompted, add the table to the current map

Display coordinates

- Right click added table and choose "display xy coordinates"
- Set XField as 'Longitude' and YField as 'Latitude'
- Right click points layer and export as shapefile to location of choice

2.2. From Table 3-8, observe which predictors are needed to apply the equation. Data source location and variable descriptions are provided in tables 3-9 and 3-10 respectively.

2.3. Use Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx) and search a location by the playa centroid using the GPS coordinates. An Area of Interest (AOI) polygon should be drawn that encompasses the playa and its general area (≈500 m circumference).

2.4. Use the "Soil Data Explorer" tab to locate necessary feature values and record results for required points.

2.5. Refer to Table 3-9 for details on locations and how to find metrics. (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053375).

3. ASUR modification

Instructions

When the ASUR modification is present in an equation, two additional location points besides the playa centroid are required. These two points are located outside of the wetland basin at 10 m and 40 m from the wetland edge. These two are averaged to determine the necessary value according to the ASUR modification.

3.1. Build necessary data points.

- From playa centroid, measure in the southwest direction (225 degrees) to playa edge
- From edge location, measure at the same angle and build two points, one 10 m and one 40 m from the SW edge

3.2. Use the Web Soil Survey and under the "Soil Data Explorer" tab, locate necessary predictors.
3.3. Determine necessary feature value for 10 m point.
3.4. Determine necessary feature value for 40 m point.
3.5. Calculate and document ASUR value by averaging the two values.

4. Soil Adjusted Vegetation Index (SAVI) (Metric H)

Instructions

4.1. Calculate Index (Choose one of the two methods below).

Basic Remote Sensing Instructions

- Use Landsat 8 spectral reflectance bands to determine index
- Red: Landsat band 4 (0.636–0.673 µm)
- NIR: Landsat band 5 (0.851–0.879 µm)
- Apply equation $SAVI = \frac{(1+L)(NIR-Red)}{(NIR+Red+L)}$

  Where L value is 0.5 (adjustment to minimize soil brightness)

Landsat 8 Image Download Instructions

- Use https://earthexplorer.usgs.gov/ to determine the name of the most recent required Landsat 8 OLI/TRS C1 Level-2 scene.
- Create a .txt file with the scene name pasted within.
- Go to USGS bulk ordering page https://espa.cr.usgs.gov/ordering/new/
- Under "Scene List" choose .txt file with scene name.
- Under "Level-2 Products" check 'Spectral Indices' and in the dropdown, select 'SAVI'
- Submit order under USGS log-in username
- Once order has been processed and sent in email, download the zipped file with type being tar.gz
- Unzip tar.gz file and save in desired folder
- Open folder in arcmap and upload SAVI scene as .tif
- Read pixel value for point of interest and scale by given factor
  - SAVI scale factor = 0.0001 (see product guide for more information) (**https://landsat.usgs.gov/sites/default/files/documents/si_product_guide.pdf)**

4.2. Determine SAVI during each season

- Estimate SAVI within or at a date nearest to each month
  - August: Summer
  - November: Fall
  - February: Winter
  - May: Spring

4.3. Average the seasonal measurements to determine a single SAVI value for a playa

Table 3-8. Equations for estimating soil organic carbon (kg/m^2) in playas with estimates based on surrounding land use and SSURGO variables. Table modified from Zhuoqing et al. (2016b).

Land-Use	***Soil Organic Carbon (kg/m^2)***	***Predictors***
Agriculture Playa Basin	Ag_SOC = POWER(5.46 – 1.955*ASUR_SAVI – 2.438*ASUR_DB + 0.00048*ASUR_RangPro + 0.027*WC – 0.778*pH + 3.921*DB,2)	ASUR_ SAVI DB RangPro WC pH
CRP Playa Basin	CRP_SOC = POWER(1.162 + 0.53*ASUR_OrgMat + 0.037*Sand – 0.124*Ksat + 0.396*Slope,2)	ASUR_ OrgMat Sand Ksat Slope
Native Grassland Playa Basin	NG_SOC = EXP (1.473 + 0.605*ASUR_EC + 0.028*ASUR_Ksat + 1.932*ASUR_SAVI – 0.356*EC – 0.192*Slope – 0.095 * ASUR_AWS)	ASUR_ EC Ksat SAVI Slope AWS

TABLE 3-9. VARIABLE NAMES AND DATA SOURCES FOR ALL PREDICTORS REQUIRED FOR SOIL ORGANIC CARBON MODELS. TABLE MODIFIED FROM ZHUOQING ET AL. (2016B).

Data Source	***Name***	***Code***	***Soil Data Explorer Tab***	***Category***	***Depth***	***Aggregation Method***	***Rating Unit***
SSURGO DATA	Range productivity (normal year)	RangPro	Suitabilities and Limitations	Vegetative Productivity	N/A	Weighted Average	lbs/ac/yr
	Representative Slope	Slope	Soil Properties and Qualities	Soil Qualities and Features	N/A	Dominant Component	percent
	Electrical Conductivity (EC)	EC	Soil Properties and Qualities	Soil Chemical Properties	0-50 cm	Dominate component	dS/m at 25 C
	pH (1 to 1 Water)	pH	Soil Properties and Qualities	Soil Chemical Properties	0-50 cm	Dominate component	pH scale
	Available Water Supply, 0 to 50 cm	AWS	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	N/A	cm
	Bulk Density, One-Third Bar	DB	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	Dominate component	g/cm^3
	Organic Matter	OrgMat	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	Dominate component	percent by weight
	Percent Sand	Sand	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	Dominate component	percent by weight
	Saturated Hydraulic Conductivity (Ksat)	Ksat	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	Dominate component	µm/s
	Water Content, One-Third Bar	WC	Soil Properties and Qualities	Soil Physical Properties	0-50 cm	Dominate component	volumetric percentage
MODIFICATIONS	10m and 40m point values required	ASUR_		Method	N/A	N/A	
SATELLITE DATA	Soil Adjusted Vegetation Index	SAVI		Vegetation	N/A	Nearest	

TABLE 3-10. VARIABLE DETAILS FOR SSURGO PREDICTORS REQUIRED FOR SOIL ORGANIC CARBON MODELS. TABLE MODIFIED FROM ZHUOQING ET AL. (2016B).

Code	Notes
RANGPRO	Total range production is the amount of vegetation that can be expected to grow annually in a well-managed area that is supporting the potential natural plant community. It includes all vegetation, whether or not it is palatable to grazing animals. It includes the current year's growth of leaves, twigs, and fruits of woody plants. It does not include the increase in stem diameter of trees and shrubs. It is expressed in lbs/ac of air-dry vegetation. In a normal year, growing conditions are about average. Yields are adjusted to a common percent of air-dry moisture content.
SLOPE	Slope gradient is the difference in elevation between two points, expressed as a percentage of the distance between those points.
EC	Electrical conductivity (EC) is the electrolytic conductivity of an extract from saturated soil paste, expressed as dS/m at 25 ° C.
PH	Soil reaction is a measure of acidity or alkalinity.
AWS	Available water supply (AWS) is the total volume of water (in cm) that should be available to plants when the soil, inclusive of rock fragments, is at field capacity. It is commonly estimated as the amount of water held between field capacity and the wilting point, with corrections for salinity, rock fragments, and rooting depth. AWS is reported as a single value (in cm) of water for the specified depth of the soil. AWS is calculated as the available water capacity times the thickness of each soil horizon to a specified depth.
DB	Bulk density, 15 bar, is the ovendry weight of the soil material less than 2 mm in size per unit volume of soil at water tension of 1/3 bars, expressed in g/cm^3.
ORGMAT	Organic matter is the plant and animal residue in the soil at various stages of decomposition. The estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 mm in diameter.
SAND	Sand as a soil separate consists of mineral soil particles that are 0.05 mm to 2 mm in diameter. The estimated sand content of 0-50 cm soil layer is given as a percentage, by weight, of the soil material that is less than 2 mm in diameter.
KSAT	Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of µm/s. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.
WC	Water content, one-third bar, is the amount of soil water retained at a tension of 1/3 bar, expressed as a volumetric percentage of the whole soil. Water retained at 1/3 bar is significant in the determination of soil water-retention difference, which is used as the initial estimation of available water capacity for some soils.
ASUR_	Metrics from points in the watershed are incorporated in this method. The modified parameter value is calculated by taking the mean of the 10 m and 40 m measurements.
SAVI	SAVI is calculated as a ratio between the R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types. It represents the extent of land with vegetation covered.

8. Plant Species Richness

REGRESSION EQUATIONS USING BASIN AND UPLAND FEATURES

Species richness of native plants within a playa basin is related to various features within and surrounding the playa. These include surrounding land use, water presence, playa size and features of nearby playas. These relationships change between changing dominant land-use types. Wetland plant species richness and native plant species richness within the playa basin can be estimated using numerous variables and equations included below (O'Connell et al. 2012).

Subregion(s): this predictive model was developed for the WHP and not recommended for use in RWB playas (Figure 3-1).

Limitations: Data used to build this model were sampled from the months of May to August. Estimates are considered most accurate for predicting Plant Species Richness values during this time.

Limitations: A limited number of plant species are likely to be found within an individual playa. With certain combinations of playa characteristics, there is potential for richness estimates to exceed ecologically relevant values. Maximum limits should be used for species richness. Wetland species should be limited to 30 and native species should be limited to 50 when high values are estimated.

COMPONENTS

- Metric C: Dominant Land Use (500 m)
- Land-use data
- Metric E: Playa Area
- Metric I: Area Total of Near Playas (within 1 km or 5 km)
- Metric J: UTM Location easterly or northerly
- Metric K: Water Presence
- Metric L: Distance to Nearest Grassland Playa
- Hydrogeomorphic Classification Key (Chapter 2)
- Table 3-11: Plant Species Richness Models

METHODS

1. **Determine Dominant Land Use (Metric C)**
   Instructions
   1.1 Establish a 500 m radius buffer around playa shape.
   1.2 Within the land-use buffer, measure or visually inspect the categories displayed in the land-use dataset and conservation program spatial data.
   1.3 Calculate (or estimate if obvious) land-use type covering > 50 % of the area within the buffer. Data source in parenthesis (Table 3-2).
      - **Cropland**: in production (CropScape: any crop type)
      - **Native Grass:** rangeland/grazing land (CropScape: 176 – Grassland/Pasture)
      - **CRP:** Conservation Reserve Program (CRP spatial data)

   1.4 Use Dominant Land Use to select necessary plant equation from Table 3-11.

2. **Use Table 3-11 to select appropriate model**
   Instructions
   2.1. Determine plant richness type of interest.
   2.2. Use Dominant Land Use to select model.

3. **Determine Playa Area (Metric E)**
   Instructions
   3.1. Calculate playa area (ha) within the playa shapefile using a GIS.

4. **Determine Area Total for Nearby Playas (1 km or 5 km) (Metric I)**
   Instructions
   4.1. Build area buffer with radius distance of 1 km or 5 km depending on metric required.
   4.2. Use NWI dataset and observe all palustrine and lacustrine waterbodies within the given buffer.
   4.3. Apply the Hydrogeomorphic HPR Identification Key and select all playas (See Chapter 2).
   4.4. Determine area of each playa and sum the values for total area of surrounding playas (ha).

5. **Determine UTM Location for playa centroid (Metric J)**
   Instructions
   5.1. Determine the coordinates of the playa centroid.

ARCMAP INSTRUCTIONS

Make data fields

- Open the wetland shapefile Attribute Table. Select Table Options > Add Field. Make a field labeled ‘Latitude’ with the field type set as double
- Repeat above steps for a field labeled ‘Longitude’

Calculate Latitude and Longitude values

- Begin an editing session for the playa shapefile
- Right click the ‘Latitude’ field and select ‘Calculate Geometry’. In this dialog box, select ‘Y Coordinate of Centroid’ from the property drop down. Units should be selected as ‘Decimal Degrees’ from the drop down.
- Repeat above for ‘Longitude’ field using the ‘X Coordinate of Centroid’

Export coordinates to a table

- In the Attribute Table, select Table Options > Export
- Select the save location and when prompted, add the table to the current map

Display coordinates

- Right click added table and choose “display xy coordinates”
- Set XField as ‘Longitude’ and YField as ‘Latitude’
- Right click points layer and export as shapefile to location of choice

   5.2. Convert lat long to UTM
   Easterly: 6 digit east-west position.
   Northerly: 7 digit north-south position.

6. **Determine Water Presence (Metric K)**
   Instructions

6.1. Use playa location to download most recent Landsat scene.
Download Landsat imagery at https://earthexplorer.usgs.gov/ .
6.2. Visually inspect the wetland location and look for water presence.
6.3. Record as 1-yes or 0-no.

7. Distance to Nearest Grassland Playa (Metric L)

Instructions

7.1. Use NWI dataset and observe all palustrine wetlands surrounding the playa of interest.
7.2. Use land-use dataset and conservation program spatial data to identify near grassland waterbodies.
7.3. Apply the Hydrogeomorphic Classification Key for High Plains Wetlands and select all grassland playas.
7.4. Use GIS measuring tool to measure the distance (km) to the nearest grassland playa.

TABLE 3-11. MODELS ESTIMATING RICHNESS FOR WETLAND PLANT SPECIES AND NATIVE PLANT SPECIES WITHIN A PLAYA BASIN. ESTIMATES ARE BASED ON LAND-USE TYPE ALONG WITH PLAYA AND NEAR PLAYA CHARACTERISTICS. TABLE MODIFIED FROM O'CONNELL ET AL. (2012).

Land Use	*Wetland Species Richness*	*Code*	*Predictor*	*Units*
Grassland	Gr_W_Richness = EXP(9.91E-01 + 1.21E-02**p_area* + 1.14E-03**5km_p* + 1.91E-06**east* + 3.25E-01* *wet*)	*p_area* *5km_p* *east* *wet*	Playa Area Playa Areas w/in 5km Easting UTM Wet Basin	ha ha 6 digits binary
CRP	P_W_Richness = EXP(4.55E+00 – 2.71E-02* *gr_dist* + 7.36E-03**1km_p* + 2.23E-06* *east* – 8.49E-07**north* + 4.98E-01**wet*)	*gr_dist* *1km_p* *east* *north* *wet*	Grass Playa Distance Playa Areas w/in 1km Easting UTM Northing UTM Wet Basin	km ha 6 digits 7 digits binary
Cropland	Cr_W_Richness = EXP(9.18E-01 + 5.27E-02**p_area* + 2.87E-02**gr_dist* + 1.62E-02**1km_p* + 2.01E-03**5km_p* – 2.86E-06**east* + 7.45E-01* *wet)*	*p_area* *gr_dist* *1km_p* *5km_p* *east* *wet*	Playa Area Grass Playa Distance Playa Areas w/in 1km Playa Areas w/in 5km Easting UTM Wet Basin	ha km ha ha 6 digits binary
Land Use	*Native Species Richness*	*Code*	*Predictor*	*Units*
Grassland	Gr_Nat_Richness = EXP(8.31E-01 – 5.16E-03**1km_p* + 7.10E-04**5km_p* + 5.15E-07**north* – 1.85E-01**wet*)	*gr_dist* *1km_p* *5km_p* *east* *north* *wet*	Grass Playa Distance Playa Areas w/in 1km Playa Areas w/in 5km Easting UTM Northing UTM Wet Basin	km ha ha 6 dgits 7 digits binary
CRP	P_Nat_Richness = EXP(2.41E+00 + 2.45E-04**5km_p*)	*5km_p*	Playa Areas w/in 5km	ha
Cropland	Cr_Nat_Richness = EXP(2.42E+00 + 3.61E-02**p_area* + 1.46E-02**gr_dist* + 8.94E-03**1km_p* + 1.42E-03**5km_p* – 2.29E-06**east* + 4.95E-01**wet*)	*p_area* *gr_dist* *1km_p* *5km_p* *east* *wet*	Playa Area Grass Playa Distance Playa Areas w/in 1km Playa Areas w/in 5km Easting UTM Wet Basin	ha km ha ha 6 digits binary

9. RWB Pollinators - Hymenoptera Abundance, Richness and Diversity

REGRESSION EQUATIONS FOR RAINWATER BASIN WETLAND, UPLAND OR COMBINED LOCATIONS

Playas in the Rainwater Basin provide pollinator habitat through the presence of flowering forbs in both the wetland basin as well as the associated upland. Hymenoptera includes bees and wasps which are important to the production of native and cultivated flowering plants. Their presence is associated with dominant land use, forb cover and playa area. The regression equations provided here are capable of estimating Abundance, Richness and Diversity for hymenoptera in differing land use types. Estimates can be made for hymenoptera within a playa, within the upland or across the two locations combined. Here, Abundance is the relative number of hymenopteran individuals sampled on transects which can be compared among differing land use/conservation program types. Richness is the total number of Hymenoptera species sampled at a site and Diversity is the number of Hymenoptera species as calculated by the Shannon's Diversity Index. Because sampling was limited to transects and sampling effort was identical across all land use types, these equations are most useful in estimating the change in hymenoptera presence among land use types (Joshi et al. 2018).

Subregion(s): developed for the RWB and ACEP. Not recommended for use in the WHP and CRP (Figures 3-1 and 3-3).

Limitations: Data used to build this model were sampled during the growing season from April to mid-October. Estimates are considered most accurate for estimating pollinator, abundance, richness and diversity during this time.

Note: to determine Metric M: Forb Coverage for a specific playa, field measurements must be taken since current land use datasets and remote sensing methods cannot simply or easily determine the presence of forbs within mixed vegetation cover. For a more general estimate, a user can select and input a mean forb coverage value calculated for land cover types from previous field measurements (see Methods part 3).

COMPONENTS

- Metric C: Dominant Land Use (500 m)
- Land-use data
- Metric E: Playa Area (ha)
- Metric M: Forb Coverage (%)
- Table 3.12: Pollinator Equations

METHODS

1. **Determine Dominant Land Use (Metric C)**
   Instructions
   1.1. Establish a 500 m radius buffer around playa shape.
   1.2. Within the land-use buffer, measure or visually inspect the categories displayed in the land-use dataset and conservation program spatial data.
   1.3. Calculate (or estimate if obvious) land-use type covering >50% of the area within the buffer. Data source in parenthesis (Table 3-2).

- **Cropland**: in production (CropScape: any crop type)
- **WRP/WRE:** Wetland Reserve Program or Wetland Reserve Easement (Geospatial Data Gateway)
- **Reference**: least disturbed wetland (Nebraska Game and Parks Commission)

1.4. Model required values for land-use type using binary values

- *Reference*: true – 1, false – 0
- *WRP/WRE*: true – 1, false – 0
- *Cropland*: default in equation (if both Reference and WRP are 0, Cropland is understood to be true)

2. Determine Playa Area (Metric E)

Instructions

3.1. Calculate playa area (ha) within the shapefile using a GIS

3.2. Pollinator models require the natural logarithm of playa area

3. Determine Total Forb Coverage by Field Measurement or select Mean Value (Metric M)

Instructions

4.1. Determine a percent total cover for forbs across wetland and upland

Field Measurement Instructions (for site specific estimate)

- Sampling should take place during the mid-growing season
- Establish random sampling transects each 25m long, 3 within the playa basin and 3 within the upland (>100m from playa edge)
- Identify forbs encountered using the step-point intercept method (Bonham 2013) and determine forb presence at each step/meter
- Determine percent sampled by dividing the number of steps/meters with forbs present by the number of steps/meters sampled
    - Percent coverage – number of forbs/150

Remote Estimate Instructions (for general estimate)

- Select total forb coverage value below based on land use
- Use total forb coverage value when solving regression equation

Percent Total Forb Coverage Mean and Standard Error

- **Agriculture:** 33.0 (±3.21)
- **Reference:** 46.85 (±3.13)
- **WRP/WRE:** 37.04 (±3.59)

4. Select Equation for estimate of interest (Table 3.12)

Instructions

6.1. Refer to table 3.12

6.2. Choose location for estimate as wetland, upland, or combined

6.3. Select equation for Abundance, Richness and/or Diversity

5. Apply Pollinator equation(s) of choice

Instructions

5.1. Use all measured metrics to populate regression equation of choice (Table 3.12)

TABLE 3-12. EQUATIONS TO ESTIMATE HYMENOPTERA ABUNDANCE, RICHNESS AND DIVERSITY IN PLAYAS, UPLANDS OR BOTH LOCATIONS COMBINED. EQUATIONS BASED ON LOCATION, DOMINANT LAND USE, PLAYA AREA AND TOTAL FORB COVERAGE (%) OF PLAYA, AND UPLAND COMBINED. TABLE MODIFIED FROM JOSHI ET AL. 2018.

Playa	**Pollinator Community Estimates**
Abundance	Playa_Abundance = EXP(2.028797 + 0.397097*reference + 0.016460*percent_total_forb + 1.173387*WRP - 0.206810*LN_Area)
Richness	Playa_Richness = EXP(1.289543 + 0.071050*reference + 0.010817*percent_total_forb + 1.056128*WRP - 0.064070*LN_Area)
Diversity	Playa_Diversity = 0.568514 + 0.132995*reference + 0.014455*percent_total_forb + 1.196403*WRP - 0.080725*LN_Area
Upland	**Pollinator Community Estimates**
Abundance	Upland_Abundance = EXP(0.344975 + 1.805519*reference + 0.053357*percent_total_forb + 1.899015*WRP - 0.383277*LN_Area)
Richness	Upland_Richness = EXP(-0.557715 + 1.563361*reference + 0.038397*percent_total_forb + 1.685239*WRP -0.234075*LN_Area)
Diversity	Upland_Diversity = 0.351641 + 0.258231*reference + 0.030272*percent_total_forb + 0.325189*WRP - 0.124080*LN_Area
Combined	**Pollinator Community Estimates**
Abundance	Combined_Abundance = EXP(1.861211 + 0.426039*reference + 0.037869*percent_total_forb + 1.325876*WRP - 0.235428*LN_Area)
Richness	Combined_Richness = EXP(1.380856 + 0.207837*reference + 0.024184*percent_total_forb + 1.029451*WRP - 0.128081*LN_Area)
Diversity	Combined_Diversity = 1.011325 + 0.197431*reference + 0.028143*percent_total_forb + 1.006147*WRP - 0.203166*LN_Area

10. Amphibian Total Species Richness

ESTIMATED BY PLAYA AND WATERSHED AREA ALONG WITH HYDROPERIOD

Amphibian presence is largely determined by hydroperiod but there are other determining habitat features. Total amphibian species richness is shown to be related to the ratio between watershed area and playa area. Richness can be estimated at a given time using these metrics (Kensinger et al. 2013).

Subregion(s): this predictive model was developed for the SHP and not recommended for use in other portions of the WHP or the RWB (Figure 3-1).

Limitations: Data used to build this model were sampled from spring inundation until playa basins were dry (October). Data was also restricted to playas with hydroperiod lengths ranging from 18 to 453 days. Estimates are considered most accurate for predicting Amphibian Species Richness during this time and under these conditions.

Note: to determine Metric O: Playa Hydroperiod satellite imagery can be used to approximate length in days or an average value for hydroperiod included below may be used if repeated field measurements to measure hydroperiod are not possible.

Note: if Metric O: Playa Hydroperiod is measured or considered to be less than 18 days, the provided equation is not suitable for estimating amphibian species richness. If hydroperiod is too short it can be concluded that amphibian species richness is 0.

COMPONENTS

- Metric E: Playa Area
- Metric N: Watershed Area
- Ratio of Watershed Area to Playa Area
- Metric O: Playa Hydroperiod
- Equation 3-3: Amphibian Species Richness

METHODS

1. **Calculate Playa Area (Metric E)**
   Instructions
   1.1. Calculate area within shapefile (ha).

2. **Determine watershed area (Metric N)**
   Instructions
   2.1. Delineate the playa watershed using a topographic map in a GIS (if Metric D: Percent Crop in Watershed was previously calculated, use watershed from step 1.1).
   ArcMap Instructions
   - Open a spatially referenced topographic map as a basemap with the playa of interest. Projections for data frame, playa polygon and topo map should be the same.
   - Create a new feature class and begin an editing session. In the Create Features window use the Construction Tool to make a polygon by placing points on all

high terrain locations surrounding the playa. For more detailed instructions on watershed delineation see https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_014819.pdf
- Save the polygon and label the watershed to correspond with the playa label.

2.2. Calculate the area within the watershed (ha).

3. **Calculate Ratio between watershed and playa**

Instructions

3.1. Calculate the ratio by dividing watershed area (ha) by playa area (ha).

4. **Determine Hydroperiod (Metric O)**

Instructions

4.1. View recent satellite imagery over multiple days to determine the length water is present in playa basin

4.2. Alternatively, users may insert an average values according to each land use type. Mean hydroperiod values in data used to develop the model across two sample years were as follows

- **Cropland**: 27 days
- **Grassland**: 53 days
- **CRP**: <18 days

4.3. Value for hydroperiod must be between 18 – 453 days to estimate richness accurately

5. **Estimate Amphibian Species Richness**

Instructions

5.1. Use hydroperiod and the ratio of watershed to playa area in the equation 3-4 below.

5.2. Calculate and record predicted species richness.

EQUATION 3-3

$$Amph\_Richness = EXP(1.0669053 + 0.0016115 * hydroperiod - 0.0020619 * ratio\ of\ watershed\ area\ to\ playa\ area)$$

11. SHP Pollinators – Hymenoptera Abundance and Richness

REGRESSION EQUATIONS FOR SOUTHERN HIGH PLAINS WETLAND OR UPLAND

Playas in the Southern High Plains provide pollinator habitat through the presence of flowering forbs in both the wetland basin as well as the associated upland. Hymenoptera includes bees and wasps which are important to the production of native and cultivated flowering plants. Their presence is associated with dominant land use, playa area, vegetation cover (%), vegetation height (cm) and precipitation (mm). The regression equations provided here are capable of estimating Abundance or Richness for hymenoptera in differing land use types and locations. Estimates can be made for hymenoptera within a playa or within the upland. Here, Abundance is the relative number of hymenopteran individuals sampled on transects which can be compared among differing land use/conservation program types. Richness is the total number of Hymenoptera species sampled at a site. Because sampling was limited to transects and sampling effort was identical across all land use types, these equations are most useful in estimating the differences in hymenoptera presence among land use types, and changes in hymenoptera presence with changes in land use type (Luttbeg et al. 2017).

Subregion(s): developed for the SHP and CRP. Not recommended for use in the RWB and ACEP (Figures 3-1 and 3-3).

Limitations: Data used to build this model were sampled during the growing season from April to September. Estimates are considered most accurate for estimating pollinator abundance and richness during this time.

Note: to determine Metrics P, Q and R for a specific playa, field measurements must be taken since current land use datasets and remote sensing methods cannot simply or easily determine the percent of each type within mixed vegetation cover. For a more general estimate, a user can select and input a mean vegetation cover and vegetation height values calculated for land cover types from previous field measurements (Table 3-13).

COMPONENTS

- Metric C: Dominant Land Use (500 m)
- Land-use data
- Metric E: Playa Area (ac)
- Metric P: Vegetation Cover (%)
- Metric Q: Vegetation Height (cm)
- Metric R: Precipitation (mm)
- Table 3-14: Pollinator Equations

METHODS

1. **Determine location of interest as upland or wetland**
   Instructions
   1.1. Model required values for location use binary values as follows
   - *Upland*: true – 1, false – 0
   - *Wetland*: default in equation (if Upland is set to 0, Wetland is understood)

2. **Determine Dominant Land Use (Metric C)**
   Instructions
   2.1. Establish a 500 m radius buffer around playa shape.
   2.2. Within the land-use buffer, measure or visually inspect the categories displayed in the land-use dataset and conservation program spatial data.
   2.3. Calculate (or estimate if obvious) land-use type covering >50% of the area within the buffer. Data source in parenthesis (Table 3-2).
   - **CRP:** Conservation Reserve Program (CRP spatial data)
   - **Cropland**: in production (CropScape: any crop type)
   - **Native Grass:** rangeland/grazing land (CropScape: 176 – Grassland/Pasture)

   2.4. Model required values for land-use type using binary values
   - *CRP*: true – 1, false – 0
   - *Cropland*: true – 1, false – 0
   - *Native Grassland*: default in equation (if both CRP and Crop are 0, Native Grassland is understood to be true)

3. **Determine Playa Area (Metric E)**
   Instructions
   3.1. Calculate playa area (ha) within the shapefile using a GIS
   3.2. Convert to acres as required by the model

4. **Determine percent Vegetation Cover (Metric P) and Vegetation Height (Metric Q) by field measurement or by selecting mean values (Table 3-13)**
   Instructions
   4.1. Determine Vegetation Cover (Metric P) as percent cover for bare ground, floral, native and non-native grass across wetland and/or upland

   Field Measurement Instructions (for site specific estimate)
   - Sampling should take place during the late-growing season (September)
   - Establish 6 random sampling transects each 25m long, 3 within the playa basin and/or 3 within the upland (upland transects should be >25m from playa edge)
   - Using the line-point intercept method (Herrick 2009), determine vegetation and ground cover
   - At each meter on the transect, determine if vegetation types are present
     - **Bare Ground**: not covered in duff (loose litter), compacted litter, or woody litter
     - **Flowering Forbs**: forbs with showy and obvious flowers
     - **Native Grass**: designated as native (see www.plants.usda.gov)
     - **Non-Native Grass:** designated as invasive (see www.plants.usda.gov)
   - Determine percent encountered by dividing the number of meters/points where a give vegetation type occurred (hits) by the number of meters/points sampled
   - Percent cover – number of “hits”/75 m (3, 25m transects in playa)

   Remote Estimate Instructions (for general estimate)
   - Select percent vegetation cover from average values provided (Table 3-13)
   - Values are from late-season field data according to land use and location

4.2. Determine Vegetation Height (Metric Q) across wetland and/or upland

Field Measurement Instructions (for site specific estimate)

- Sampling should take place during the late-growing season (September)
- Establish 6 random sampling transects each 25m long, 3 within the playa basin and/or 3 within the upland (upland transects should be >25m from playa edge)
- Using the line-point intercept method (Herrick 2009), measure the height of vegetation (cm) in 2 meters intervals beginning at the 1 meter mark
- Measurements should be taken 10 cm out from the transect line
- Pool height values by location and determine the mean height value for the playa and mean height value for the upland

Remote Estimate Instructions (for general estimate)

- Select vegetation height from average values provided (Table 3-13)
- Values from late-season field data according to land use and location

5. Determine average monthly Precipitation (Metric R) for the growing season (Apr-Sept)

Instructions

5.1. Identify West Texas Mesonet monitoring station nearest to sampling site www.mesonet.ttu.edu

5.2. Calculate the average monthly precipitation from April to September for the year of interest by adding the monthly rainfall values and dividing by 6

5.3. If estimates are taking place during mid-growing season, precipitation from late-season months can be estimated using values from the previous year

5.4. Convert rainfall values to millimeters

6. Select and apply equation for estimate of interest (Table 3-14)

Instructions

6.1. Refer to table 3-14

6.2. Select equation for Abundance or Richness

TABLE 3-13. MEAN (±) VEGETATION COVER VALUES FOR EACH LAND USE TYPE IN BOTH PLAYAS AND UPLANDS IN THE SOUTHERN HIGH PLAINS. VALUES CAN BE USED TO POPULATE THE PREDICTIVE MODEL TO ESTIMATE HYMENOPTERA ABUNDANCE AND RICHNESS. DATA FROM DATA USED IN BEGOSH (2017).

	Cropland				**CRP**				**Native Grassland**			
	Playa	(SE)	Upland	(SE)	Playa	(SE)	Upland	(SE)	Playa	(SE)	Upland	(SE)
Bare Ground (%)	52.89	(8.47)	41.85	(8.20)	69.63	(7.55)	39.19	(5.43)	66.67	(7.60)	64.96	(3.20)
Flower Cover (%)	18.30	(5.74)	12.22	(5.53)	8.67	(2.49)	3.93	(0.78)	12.47	(2.09)	11.55	(3.50)
Native Grass (%)	2.00	(1.62)	7.85	(3.23)	9.41	(4.12)	35.19	(5.80)	30.43	(5.86)	52.30	(4.82)
Non-Native Grass (%)	9.70	(3.68)	13.56	(4.57)	11.63	(5.09)	32.15	(7.12)	9.57	(3.64)	2.07	(0.68)
Vegetation Height (cm)	22.20	(4.33)	46.46	(7.37)	22.00	(3.20)	28.49	(3.92)	12.45	(2.64)	18.72	(3.63)

TABLE 3-14. EQUATIONS TO ESTIMATE HYMENOPTERA ABUNDANCE AND RICHNESS IN SOUTHERN HIGH PLAINS PLAYAS OR UPLANDS DOMINATED BY THREE LAND USE TYPES. EQUATIONS CAN BE SOLVED FOR LOCATION (UPLAND: 1=TRUE, 0=FALSE) AND DOMINANT LAND USE (CONSERVATION RESERVE PROGRAM (CRP), CROP: 1=TRUE, 0=FALSE). METRICS INCLUDE PLAYA AREA IN ACRES (AREA), PERCENT VEGETATIVE COVER (BARE_GROUND, FLORAL, NATIVE_GRASS, NON-NATIVE_GRASS), PRECIPITATION IN MILLIMETERS (PRECIP) AND VEGETATION HEIGHT IN CENTIMETERS (VEG_HEIGHT). TABLE MODIFIED FROM LUTTBEG ET AL. (2017).

	SHP Pollinator Community Estimates
Abundance	Abundance = EXP(3.74 + 0.283*upland + 1.772*CRP + 1.511*crop + 0.009*area + 0.011*bare_ground + 0.023*floral + 0.013*native_grass – 0.008*non-native_grass + 0.027*precip + 0.009*veg_height – 0.01*(CRP*area) – 0.005*(crop*area) – 0.004*(upland*bare) – 0.013*(CRP*bare) – 0.007*(crop*bare) – 0.027*(CRP*floral) – 0.025*(crop*floral) – 0.014*(CRP*native_grass) – 0.021*(crop*native_grass))
Richness	Richness = EXP(3.393 + 0.061*upland + 0.159*CRP + 0.09*crop + 0.002*bare + 0.002*floral + 0.016*precip + 0.006*veg_height – 0.002*(CRP*bare) – 0.003*(crop*bare) – 0.002*(CRP*floral) – 0.002*(crop*floral) – 0.004*(CRP*veg_height) – 0.003*(crop*veg_height) – 0.036*(CRP*upland) + 0.015*(crop*upland))

12. Avian Total Species Richness and Waterfowl Abundance

ESTIMATED BY PLAYA AND UPLAND CHARACTERISTICS

Suitable playa habitat for avian species requires water presence. Avian total species richness and waterfowl abundance, specified as duck and goose abundance combined, can be estimated for a playa in each season. These estimates are built on habitat and hydrology features for the playa of interest as well as the surrounding upland. Once the season of interest is selected the necessary metrics can be obtained for the given equations (Kensinger et al. 2015).

Subregion(s): this predictive model was developed for the SHP and not recommended for use in other portions of the WHP or the RWB (Figure 3-1).

Note: If Metric K: Water Presence is determined as 0 (absent) the provided equation will overestimate waterfowl abundance. If no water is present it can be concluded that waterfowl abundance is 0.

Note: to include Metric M: Playa Water Depth, average values provided below may be incorporated if determining water depth using repeated in field measurements is not possible.

COMPONENTS

- Metric E: Playa area (ha)
- Metric K: Water Presence
- Metric N: Watershed Area (ha)
- Metric S: Water Depth (cm)
- Metric T: Tilled Index
- Land-use data
- Table 3-15: Models for Avian Total Species Richness and Waterfowl Abundance

METHODS

1. **Select appropriate model from Table 3-15.**
   Instructions
   1.1. Select between avian total species richness or waterfowl abundance for estimate.
   1.2. Identify season of interest for estimates and determine necessary metrics.

2. **Determine Playa Area (Metric E)**
   Instructions
   2.1. Calculate playa area (ha) within the shapefile using a GIS.

3. **Determine Water Presence (Metric K)**
   Instructions
   3.1. Use playa location to download the Landsat scene nearest to date of interest with adequate visibility (low cloud cover).
   Download Landsat imagery at https://earthexplorer.usgs.gov/.
   3.2. Visually inspect the wetland location and look for water presence.
   3.3. Record as 1-yes or 0-no.

4. Determine Watershed Area (Metric N)

Instructions

4.1. Delineate the playa watershed using a topographic map in a GIS (if Metric D: Percent Crop in Watershed was previously calculated, use watershed from step 1.1).

ArcMap Instructions

- Open a spatially referenced topographic map as a basemap with the playa of interest. Projections for data frame, playa polygon and topo map should be the same.
- Create a new feature class and begin an editing session. In the Create Features window use the Construction Tool to make a polygon by placing points on all high terrain locations surrounding the playa. For more detailed instructions on watershed delineation see https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_014819.pdf
- Save the polygon and label the watershed to correspond with the playa label.

4.2. Calculate the area (ha) within the watershed

5. Estimate Water Depth (Metric S)

Instructions

5.1. Users can insert an average value for water depth based on season and land use. Mean water depth values are from data used to develop the models

Cropland	Native Grassland	CRP
Fall: 29.43 cm	Fall: 27.16 cm	All Seasons: 0 cm
Winter: 20.14 cm	Winter: 26.47 cm	
Spring: 11.09 cm	Spring: 17.27 cm	
Summer: 42.76 cm	Summer: 34.63 cm	

5.2. If Metric K: Water Presence is considered 0 (absent), the water depth value should be considered 0 cm in model calculations

5.3. In CRP land use, water depth is considered 0 cm when field measurements cannot be taken. This requires water presence to be considered 0 (absent) even in water is visible from imagery. Water in CRP playas generally does not reach sufficient depths for a long enough time period to be considered usable by waterfowl.

6. Determine Tilled Index (Metric T) (Tsai et al. 2007)

Instructions (Tsai et al. 2007)

6.1. Delineate the playa watershed using a topographic map in a GIS. (if Metric D: Percent Crop in Watershed was previously calculated, use watershed).

ArcMap Instructions

- Open a spatially referenced topographic map as a basemap with the playa of interest. Projections for data frame, playa polygon and topo map should be the same.
- Create a new feature class and begin an editing session. In the Create Features window use the Construction Tool to make a polygon by placing points on all high terrain locations surrounding the playa. For more detailed instructions on

watershed delineation see https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_014819.pdf

- Save the polygon and label the watershed to correspond with the playa label.

6.2. Using a land-use dataset and conservation program spatial data, identify all land uses within the watershed.

6.3. Measure the area of tilled land and the area of untilled land. Data source in parenthesis (Table 3-1).

- **Tilled lands**: cropland (in production, CropScape: any crop type) and CRP (CRP spatial data)
- **Untilled land**: native grass (CropScape: 176 – Grassland/Pasture)

6.4. Apply equation 3-4 to determine the Tilled Index (TI).

Values range from -1(untilled watershed) to +1(tilled watershed)

EQUATION 3-4

$$Tilled\ Index(TI) = \frac{Tilled\ landscape - Untilled\ landscape}{Tilled\ landscape + Untilled\ landscape}$$

7. Apply the appropriate model and record predicted avian values

7.1. Select model based on season and service of interest from table 3-15 and solve the given equation using the necessary metrics.

Table 3-15. Models estimating avian species richness and waterfowl abundance in a playa. Estimates are based on season along with playa and near playa characteristics. Table modified from Kensinger et al. (2015).

Season	*Total Avian Species Richness*	*Code*	*Predictor*	*Units*
Fall	$\text{F\_Richness} = \text{EXP}(-0.10 - 0.0011*WD + 1.09*WET + 0.031*PA + 0.31*TI)$	*WD*	Water Depth	cm
		WET	Water	binary
		PA	Playa area	ha
		TI	Tilled index	none
Winter	$\text{W\_Richness} = \text{EXP}(-0.37 + 0.69*WET - 0.0005*WA + 0.043*PA + 0.22*TI)$	*WET*	Playa wetness	binary
		WA	Watershed area	ha
		PA	Playa area	ha
		TI	Tilled index	none
Spring	$\text{Sp\_Richness} = \text{EXP}(0.66 + 0.0011*WD + 1.03*WET - 0.00012*WA + 0.02*PA + 0.13*TI)$	*WD*	Water depth	cm
		WET	Water	binary
		WA	Watershed area	ha
		PA	Playa area	ha
		TI	Tilled index	none
Summer	$\text{Su\_Richness} = \text{EXP}(0.87 - 0.0048*WD + 0.85*WET + 0.00014*WA + 0.025*PA + 0.27*TI)$	*WD*	Water Depth	cm
		WET	Water	binary
		WA	Watershed area	ha
		PA	Playa area	ha
		TI	Tilled index	none
Season	*Total Waterfowl Abundance*	*Code*	*Predictor*	*Units*
Fall	$\text{F\_WF\_Abundance} = \text{EXP}(-4.86 - 0.0077*WD + 7.11*WET + 0.00015*WA + 0.104*PA + 0.43*TI)$	*WD*	Water Depth	cm
		WET	Water	binary
		WA	Watershed area	ha
		PA	Playa area	ha
		TI	Tilled index	none
Winter	$\text{W\_WF\_Abundance} = \text{EXP}(-3.57 + 0.0201*WD + 0.27*WET - 0.0023*WA + 0.229*PA)$	*WD*	Water Depth	cm
		WET	Water	binary
		WA	Watershed area	ha
		PA	Playa area	ha
Spring	$\text{Sp\_WF\_Abundance} = \text{EXP}(-3.53 + 0.0639*WD + 4.09*WET + 0.066*PA)$	*WD*	Water Depth	cm
		WET	Water	binary
		PA	Playa area	ha
Summer	$\text{Su\_WF\_Abundance} = \text{EXP}(-4.59 - 0.0198*WD + 5.47*WET + 0.00085*WA + 0.076*PA)$	*WD*	Water Depth	cm
		WET	Water	binary
		WA	Watershed area	ha
		PA	Playa area	ha

Example Application on a WHP Playa

Values estimated for an example playa are included below. The playa of interest was selected from the Playa Lakes Joint Venture Probable Playas dataset (Playa Lakes Joint Venture 2011) and was in Baca County, Colorado and within the boundaries of the Comanche National Grassland (Figure 3-4). The dominant surrounding land use of the playa was identified as grassland in CropScape, and the playa area was 10.43 ha. All models except for RWB Hymenoptera were applied to this playa as an illustration of how services might be estimated. The SHP hymenoptera model was used to provide pollinator estimates since the playa of interest is in a region mores similar to the SHP than the RWB. For all other models, location of playa was not considered when applying models but should be considered when seeking to most accurately estimate service provisioning. Values here are provided only as an example. Ecosystem service estimates for the current playa conditions are included in Table 3-16.

Services can be compared and modeled under potential future conditions. If land use was converted from grassland to cropland without an established vegetative buffer, mean pesticide residues of runoff are estimated to increase from 0.0363 ppm to 0.272 ppm nitrogen and from 0.6837 ppm to 1.443 ppm phosphorous. Similarly, greenhouse gas flux in the grassland is estimated to be 17,465 g C/ha/day, and when modeled under cropland conditions would increase to 27,3211 g C/ha/day. Under grassland conditions, this playa is estimated to support 16 different upland plant species and 16 wetland plant species. If land use was converted to cropland, those numbers would be reduced to 5 upland species and 1 wetland species.

FIGURE 3-4. SATELLITE IMAGERY OF A COLORADO PLAYA IDENTIFIED BY THE PLAYA LAKES JOINT VENTURE PROBABLE PLAYA DATASET (PLAYA LAKES JOINT VENTURE 2011). DATA FROM ESRI (2018).

TABLE 3-16. ECOSYSTEM SERVICE ESTIMATES FOR GRASSLAND PLAYA IN COLORADO

Ecosystem Services	***Estimate***
1. Contaminant Filtration A. Vegetative Buffer Type – Native Grassland	Nitrogen: 76.46 % Phosphorous: 76.13 %
2. Contaminant Concentration B. Vegetative Buffer Width – 60 m	Nitrogen: 0.0363 ppm Phosphorous: 0.6837 ppm
3. Pesticide Residue C. Dominant Surrounding Land Use (500 m) – Native Grassland	Atrazine: 0.42 µg/kg
4. Sediment Depth D. Percent Crop in Watershed – 8.09 %	4.06 cm
5. Floodwater Storage E. Playa Area – 10.43 ha	25,047.53 m^3
6. Greenhouse Gas Flux F. MODIS – LAI – 0.2	17,4565.8 g/C/ha/day
7. Soil Organic Carbon G. SSURGO: ASUR_EC – 0.1 dS/m ASUR_Ksat – 1.601 um/s EC – 0.1 dS/m Slope – 1 % ASUR_AWS – 7.67 cm H. SAVI – 0.1011	Grassland: 2.27 kg/m^2
8. Plant Species Richness E. Playa Area – 10.43 ha I. Area of all Near Playas 1 km – 0 ha 5 km – 23.34 ha J. UTM: East – 690228.85 North – 4116040.18 K. Water Presence – 1	Wetland Species: 16.24 Upland Species: 16.16
10. Waterfowl Abundance E. Playa Area – 10.43 ha K. Water Presence – 1 M. Water Depth – 37 cm N. Tilled Index – 0.43 O. Watershed Area – 630.66 ha	Fall Abundance: 16 Summer Abundance: 4

TABLE 3-16. CONTINUED

11. SHP Pollinators Hymenoptera Community C. Dominant Land Use – Native Grassland E. Playa Area – 22.75 acres P. Vegetation Cover (%) Bare Ground: Playa – 66.67, Upland – 64.96 Flowers: Playa – 12.47, Upland – 11.55 Native Grass: Playa – 30.43, Upland – 52.3 Non-Native Grass: Playa – 9.57, Upland – 2.07 Q. Vegetation Height Playa – 12.45 Upland – 18.72 R. Precipitation: 38.43 mm	Playa Abundance: 640 Upland Abundance: 939 Playa Richness: 69 Upland Richness: 76
12. Amphibian Total Species Richness E. Playa Area – 10.43 ha O. Watershed Area – 630.66 ha P. Hydroperiod – 98 days	Species Richness: 3

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Appendix A: List of Metrics for Models

Appendix B: Data Sheets for Models

Datasheets are provided for ease of use and metrics can be handwritten in the available cells. Many models do not require all metrics in datasheet, see instructions to determine which metrics to select. See example of plant species richness below.

Playa ID: Example27 Date: 1/20/19

8. Native Plant Species Richness

Predictors from Table 3-10

Metric C: Dominant Land Use	Grassland
Metric E: Playa Area	10.43 ha
Metric I: Area Near Playas	1 km 0 ha
	5 km 23.34 ha
Metric J: UTM	East: 690228.85
	North: 4116040.18
Metric K: Water Presence	Yes - 1
Metric L: Distance to Nearest Grassland Playa	2 km

Apply Table 3-10

Wetland Species Richness	16.23
Upland Species Richness	16.15

Playa ID: Date:

1. Percent Contaminant Filtration (%)

Metric A: Vegetative Buffer Type	

Apply Table 3-3

Contaminant	**Filtration %**	SE

Playa ID: Date:

2. Contaminant Concentration (ppm)

Metric B: Mean Buffer Width	m

Apply Table 3-4

Contaminant	**Concentration (ppm)**	SE

Playa ID: Date:

3. Pesticide Residue (ug/kg)

Subregion:	
Metric C: Dominant Land Use	

Apply Table 3-5 Pesticide Residue

Pesticide	**Concentration (ug/kg)**	SE

Playa ID: Date:

4. Sediment Depth (cm)

Apply Equation 3-1

Cropped Area		ha
Total Area		ha
Metric D: Percent Crop in Watershed		%

Apply Equation 3-2

Sediment Depth (cm):		cm

Playa ID: Date:

5. Floodwater Storage (m^3)

Metric E: Playa Area	ha

Apply Table 3-6 (Ovol)

Original Volume (OVol)	m^3

Apply Table 3-6 (% Lost)

Percent Lost (%Lost)	%

Apply Table 3-6 (Lvol)

Total Volume Lost (Lvol)	m^3

Apply Table 3-6 (FwSt)

Floodwater Storage (FwSt)	m^3

Playa ID: Date:

6. Greenhouse Gas Flux (g C/ha/day)

Metric C: Dominant Land Use	

Table 3-7 Choose LAI or FPAR

Metric F: MODIS	LAI:	ha
	FPAR:	%

Apply Table 3-7

Greenhouse Gas Flux		g C/ha/day

Playa ID: Date:

7. Soil Organic Carbon (kg/m^2)

Metric C: Dominant Land Use	

Predictors from Table 3-8

Metric G: SSURGO

RangPro	lbs/ac/yr	OrgMat	% by wt
ASUR_RangPro	lbs/ac/yr	Sand	% by wt
10m value		Ksat	um/s
40m value		ASUR_Ksat	um/s
Slope	%	10m value	
EC	dS/m	40m value	
ASUR_EC	dS/m	WC	vol %
10m value			
40m value		Metric H: SAVI	
pH		ASUR_SAVI	
AWS	cm	10m value	
ASUR_AWS	cm	40m value	
10m value			
40m value			
BD	g/cm3		
ASUR_BD	g/cm3		
10m value			
40m value			

Apply Table 3-8

Soil Organic Carbon	kg/m^2

Playa ID: Date:

8. Native Plant Species Richness

Predictors from Table 3-18

Metric C: Dominant Land Use		
Metric E: Playa Area		ha
Metric I: Area Near Playas	1 km	ha
	5 km	ha
Metric J: UTM	Easting:	
	Northing:	
Metric K: Water Presence		
Metric L: Distance to Nearest Grassland Playa		km

Apply Table 3-11

Wetland Species Richness	
Upland Species Richness	

Playa ID: Date:

9. RWB Pollinator Abundance, Richness, Diversity

Metric C: Dominant Land Use	
Metric E: Playa Area	ha
LN of Playa area	
Metric M: Forb Coverage	%

Apply Table 3-12

Playa	Abundance:
	Richness:
	Diversity:
Upland	Abundance:
	Richness:
	Diversity:
Combined	Abundance:
	Richness:
	Diversity:

Playa ID: Date:

10. Amphibian Total Species Richness

Determine Ratio

Metric E: Playa Area	ha
Metric N: Watershed Area	ha
Ratio	

Metric O: Playa Hydroperiod	days

Apply Equation 3-3

Amphibian Species Richness	

Playa ID: Date:

11. SHP Hymenoptera Abundance and Richness

Metric C: Dominant Land Use	
Metric E: Playa Area	ha
Metric P: Vegetation Cover	
Bare Ground	%
Flowering Forbs	%
Native Grass	%
Non-Native Grass	%
Metric Q: Vegetation Height	cm
Metric R: Precipitation	mm

Apply Table 3-14

Playa	Abundance:
	Richness:
Upland	Abundance:
	Richness:

Playa ID: Date:

12. Avian Species Richness and Waterfowl Abundance

Metric E: Playa Area (PA)		ha
Metric K: Water Presence (WET)		binary
Metric N: Watershed Area (WA)		ha
Metric S: Water Depth (WD)		cm
Tilled Watershed Area		ha
Total Watershed Area		ha
Metric T: Tilled Index (TI)		

Apply Table 3-15

Total Avian Species Richness	Fall:
	Winter:
	Spring:
	Summer:
Total Waterfowl Abundance	Fall:
	Winter:
	Spring:
	Summer: